International Union of Forest Research Organizations

Policies and Instruments for the Adaptation of Forests and the Forest Sector to Impacts of Climate Change as Indicated in United Nations Framework Convention on Climate Change National Reports

Prepared by Geoff Roberts

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List of Acronyms

CBD – Convention on Biological Diversity

CBO – Community Based Organisation

CO_2 – Carbon Dioxide

CPF – Collaborative Partnership on Forests

ENSO – El Niño Southern Oscillation

FAO – Food and Agriculture Organization of the United Nations

FRA – Global Forest Resources Assessment

FSC – Forest Stewardship Council

GDP – Gross Domestic Product

GEZ – Global Ecological Zone

GHG – Greenhouse Gases

IPCC – Intergovernmental Panel on Climate Change

IUFRO – International Union of Forest Research Organizations

NAPA – National adaptation programmes of action

NC – National communications

NGO – Non-Governmental Organization

PCFE – Programme for the Endorsement of Forest Certification schemes

SciTech – Joint Initiative on Forest Science and Technology of the Collaborative Partnership on Forests (CPF)

SFM – Sustainable Forest Management

UNFCCC – United Nations Framework Convention on Climate Change

UNFF – United Nations Forum on Forests

Executive Summary:

This report has been created for the Expert Panel on Adaptation of Forests to Climate Change established under the Joint Initiative on Forest Science and Technology of the Collaborative Partnership on Forests (CPF), and prepared under the direction and supervision of the International Union of Forest Research Organizations (IUFRO).

The objective of this report is to determine the impacts and vulnerabilities of forests and the forest sector to climate change and if corresponding policies and instruments have been implemented to promote the adaptation of forests and the forest sector. This was achieved through the analysis of 95 National Communications (NCs) and national adaptation programmes of action (NAPAs) produced for the United Nations Framework Convention on Climate Change. Information was delineated into the topical, sub-tropical, temperate and boreal domains.

The analysed reports indicate that impacts of climate change have already been observed in all domains and are anticipated to continue. This is generally associated with an increase in temperature, changes in precipitation, and an increase in the occurrence of extreme weather events and disturbances, resulting in regional forest degradation and changes in species composition and phenology. The most vulnerable forests are those with limited dispersal capacity, such as mountainous species, or degraded and stressed forests, such as those located at the limits of ecological zones or growing conditions.

The forests that are located in developing countries, in particular in the tropical domain, appear to be in more immediate danger from deforestation and anthropogenic degradation which is predicted to be exacerbated by climate change. NAPA projects aimed at afforestation, community based forest management and community forests are commonly promoted. However, a lack of funding is a likely inhibitor to many of the projects mentioned within the NAPAs.

Significant amounts of research into vulnerabilities and impacts of climate change and mitigation are reported by most countries, while research into adaptation is comparatively less, and policy introduced specifically for the adaptation of forests and

the forest sector is limited. Specific policy related to adaptation of forests to climate change tends to be focused on general vulnerability, rather than at specific vulnerabilities. These policies are often in the form of national programmes and forest acts with the principle objective of sustainable forest management (SFM) (regulatory instruments; Forest Acts, national forest programmes), afforestation (economic instruments; subsidies, tax incentives, compensatory payments), and capacity building through education and increased awareness (informational instruments; monitoring, risk assessment, national forest programmes).

Numerous countries refer to a National Adaptation Plan which is reported to contain adaptation options, or to the need for such a programme to be developed. Specific examples of adaptation options which have been implemented are scarcer.

Existing policies and projects reported in NCs and NAPAs tend to focus on minimising the impact of climate change by preserving existing forests ecosystems, rather than changing them to minimise the damage in the future.

The NCs and NAPAs reflect that some forest management and policy options can fulfil the objectives of adaptation, mitigation and sustainable development. As exemplified by SFM and afforestation, which can increase the natural resilience of forests and promote adaptation, while simultaneously maintaining or improving the level of carbon sequestration. Similarly, the incorporation of adaptation into mitigation is needed to ensure the longevity of mitigation programmes.

The analysis indicates limitations in policies promoting the adaptation of forests and the forest sector, in that specific anticipatory policies relating to a stated vulnerability are rarely reported. Many reports refer to SFM, but fail to specify which particular policies are taken in order to adapt to the environmental changes caused by climate change. Similarly, there appears to be a lack of precise measures mentioned within the analysed reports relating to what constitutes SFM, and the correlation between SFM and adaptation to climate change. Therefore, it is concluded that there are programme deficits. However, it is not possible to determine if this represents the true circumstances or if it is reflecting the broad nature of the national reports, of which forests and the forest sector only form a small subset.

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Synthesised Report:

This report has been created for the Expert Panel on Adaptation of Forests to Climate Change established under the Joint CPF Initiative on Forest Science and Technology of the Collaborative Partnership on Forests (CPF), and prepared under the direction and supervision of the International Union of Forest Research Organizations (IUFRO).

Policy programmes and instruments for the adaptation of forests to impacts of climate change aim at enabling forest owners and forest managers to take appropriate means in time for ensuring sustainable management of forests (SFM) under the changed conditions of global warming. Section III.2 of the assessment report of the Expert Panel on Adaptation of Forests to Climate Change on policy options builds upon the preceding section III.1 on forest management options and, in addition, on already existing policy programmes and instruments of nation states; the latter has been collected and collated from all post 2004 UNFCCC National Communications (NCs) and National Adaptation Programmes of Action (NAPAs) within this report, as commissioned by the IUFRO Secretariat. The report divides the world forests into tropical, sub-tropical, temperate, and boreal domains, in accordance with the classification of the Global Forest Resources Assessment (FAO, 2001a). For each forest domain “observed impacts”, “vulnerabilities and future impacts”, “social impacts”, “forest management measures”, “policies for adaptation and instruments”, and “mitigation measures” are distinguished. The rationale of the report is to look for programme deficits; they exist if there are vulnerabilities of forests but no appropriate policy tools to adapt to them. In the following an abridged version of the policy programmes and instruments are represented for the four forest domains.

Tropical Domain[1]

Observed Impacts: The tropical domain is predicted to experience an increase in temperature, with an overall decrease in precipitation, although this may differ between regions with some areas predicted to have an increase in rainfall (e.g. mountainous regions and regions with bimodal rainfall patterns). The forests of the tropical domain/developing nations are at significant risk due to climate change. This is a result of high anthropogenic stress existing on the forests, which is expected to be exacerbated by climate change induced events such as fire, flood, drought, storm surges, insects, diseases and general aridity.

Vulnerabilities and Future Impacts: Vulnerability is intrinsically linked with adaptive capacity, which can be significantly hampered by limitations in financial and human resources. As a significant proportion of the forests in the tropical domain are located in countries with a developing economy with more limited financial resources, this may have significant ramifications on the vulnerability of the domain to climate change. Furthermore, many of the forests located in the tropical domain are currently being seriously degraded, deforested and exploited through anthropogenic activities which have inherently weakened the forests resilience to climate change. Of particular relevance to the tropical domain is rampant deforestation, largely at the benefit of agricultural lands, but also for the collection of timber and non-timber resources. Deforestation has significant implications in relation to climate change as decreased area and fragmentation increases vulnerability to climate change, as well as acts as a major source to CO_2 emissions (through burning, lost soils stores and sink potential) and significantly reduces the adaptive capacity of forests and communities. In addition, deforestation leads to a loss of ecosystem services, such as watershed and soil protection, which will have detrimental effects on the social arena. Similarly, the drivers of forest degradation are often for subsistence purposes, such as building

[1] Tropical Annex I countries include Australia and the United States of America, with Non-Annex I countries being Brazil, Cameroon, Fiji, Gabon, Guinea-Bissau, India, Madagascar, Mexico, Nepal, Rwanda, Saudi Arabia, Sierra Leone, Sao Tome and Principe, Solomon Islands, Suriname, Tonga, Turkmenistan, United Arab Emirates, Venezuela while countries who produced a NAPA include; Benin, Burkina Faso, Djibouti, Guinea, Haiti, Madagascar, Mali, Democratic Republic of Congo, Senegal, Bangladesh, Bhutan, Burundi, Cambodia, Cape Verde, Comoros, Eritrea, Guinea-Bissau, Kiribati, Malawi, Mauritania, Niger, Rwanda, Samoa, Sao Tome and Principe, Sudan, Tanzania, Tuvalu, Vanuatu, Zambia.

materials, food and fuel wood. This degradation has been exacerbated though increasing population pressure, and resulted in the degradation of formally protected forests, increasing forests vulnerability to climate change. Although traditionally fuel wood consisted of dead wood, in countries where there has been a progressively urbanized population and expansion of coal fuelled heating systems, growing forests have been increasingly targeted to meet the demands, leading to further forest degradation. In summation, many of the forests in the tropical domain are in a fragile state in countries with limited socio-economic resources for adaptation, thus highly vulnerable to climate change.

Coastal forests, such as mangroves, are important stabilizers in coastal environments, contributing to the prevention of coastal erosion. However, these coastal ecosystems are vulnerable to the impacts of extreme weather events, in particular to ocean surges, cyclones, as well as inundation due to increased sea levels. Mangrove forests are also at risk of deforestation for agriculture and aquaculture.
Mountainous regions are expected to experience an increase in landslides as a result of climate change and deforestation. Mountain forests are also at risk as a result of limited ability and area to migrate, as well as from increased competition from lower altitude species.

Species composition and the structure of forests are expected to change. It is predicted that there will be a poleward and upward (up to 500m in elevation) migration of forest types as a result of climate change. In general terms, in areas where rainfall is predicted to decrease the species composition will change in favour of dry forests, woodlands and savannas and a decrease in vegetative biomass, whilst in the regions where rainfall is expected to increase it is expected that there will be a shift to moist/wet forests and an increase in vegetative biomass. However, the rate of climate change is predicted to exceed species natural ability to adapt, which may led to forest degradation.

The tropical domain is predicted to experience an increase in extreme weather events and disturbances which will impact on forest health and biodiversity, including drought, fire, wind, floods, landslides, pests and diseases.

An overriding issue throughout the NAPAs and NCs is that many countries in the tropical region have a low GDP per capita and a high percentage of their population that is exerting pressure on the national environment for subsistence, in particular on forests for the collection of fuel wood. Climate change is predicted to exacerbate the existing anthropogenic stress on the forest ecosystems. Subsequently, it is predicated there will be an increase of the social problems and poverty (i.e. lack of food, fuel wood, and building materials), which again increases stress on the natural environment as the population attempts to meet their living requirements, thus forming a viscous cycle of social and environmental degradation.

It is reported that woman and children, as the predominant collectors of fuelwood, are likely to be the most impacted by a loss of forests as they will be required to travel further distances. Communities may experience further hardship as climate change may impact on food trees such as coconut and bread fruit, through the extended dry periods. To cope with the loss of fuel-wood and to reduce the anthropogenic impacts on primary forests, some nations aim to use policy to promote the use of non-timber fuel for heating and cooking, including solar, wind, and gas. Agroforestry is commonly promoted as a means of mitigating the potential impacts of climate change on the environmental and social sector.

Forest Management Measures: The application of community based forest management aimed at promoting afforestation and the conservation of land, water and timber resources is commonly promoted within national reports. India reports on short-term rotation species and management practices to increase the resilience of forests to climate change. SFM is also reported as a method of increasing the resilience of forests to climate change. Changes in forest management, such as harvesting and planting dates, and utilization of thinning are further possible methods of adapting to climate change.

Policies for Adaptation and Instruments

A significant inhibitor of adaptation for many of the countries located in the tropical domain is insufficient financial and human resources to create and implement policy programmes and projects on adaptation to climate change. This limitation can extend to the community level due to forest dependence and subsistence conditions. It is

noted that by delaying the implementation of policies dealing with adaptations to climate change, it may increase the vulnerability of systems and/or increase the costs of adapting. This may have significant ramifications for developing nations which are already facing financial limitations for adaptation. Within the domain there is a notable trend of utilizing community based projects to mitigate and adapt to the predicted impacts of climate change. This includes community afforestation projects, and strengthening community based and participatory forest management. From the reviewed reports it appears that the forests of the tropical domain are under imminent threat from anthropogenic degradation, which will be exacerbated by climate change.

Regulatory instruments: Forest conservation, in the form of formal protection areas and SFM is highlighted as an adaptation option to climate change. Throughout the tropical domain there are problems with the implementation of regulatory policy, such as protective areas, due to a lack of resources for the enforcement of such measures. As a result protected areas continue to be degraded through illegal anthropogenic practices and exceeding of cutting concessions. Efforts to combat deforestation are also reported to be limited by poor policy coupled with insufficient means for enforcement. Thus, institutional strengthening of departments and bodies concerned with forest management, research and protection, including their ability to enforce legislation, is identified as a necessary step decreasing the vulnerability of forest to climate change. This is reported to be achieved through increasing the human and technological resources.

Regulatory tools are generally associated with national forest programmes (nfps) or equivalents. They promote SFM, afforestation, monitoring, forest protection, and recognition of indigenous people. It is also reported that forest harvesting should be limited by the capacity to regenerate and should be flexible to respond to changes in forest condition and health, and overall there is a need for the promotion of reforestation.

Economic instruments: The utilization of financial instruments for adaptation to climate change was comparatively limited within the tropical domain. Community based projects and national afforestation projects have been initiated throughout the tropical domain. Despite afforestation efforts it is also reported that the amount is

insufficient to compensate the level of deforestation. Brazil suggests that a "protector receives" system as opposed to "polluter pays" is a good mechanism for environmental protection in poverty stricken regions. It is reported that poorer communities are more likely to act when there are financial incentives rather than disincentives. This could be distributed through "Ecological ICMS" (Ecological Tax on the Circulation of Goods and Services).

Financial incentives for SFM, reforestation and changes to non-wood based fuels are mentioned as a means of promoting adaptation, however it is also noted that a lack of financial resources may impede the utilisation of economic instruments.

Informational instruments: Besides nfps, capacity building through the dissemination of information (i.e. training, research etc.) is frequently mentioned throughout NAPAs and NCs. Information on the current situation of forests is required in order to determine baseline figures, identify vulnerable forest type and develop appropriate adaptation options. There is a need for the incorporation of climate change into short- to long-term planning at all levels of decision making, from forest management plans to the long-term policy making process.

The utilization of forests as a means of protecting communities and the ecosystem benefits, in particular the protection of watersheds, is well documented in the NAPAs and NCs. This is achieved through the afforestation of coastal and mountainous areas. The implementation of afforestation projects is commonly linked with the national forest or environmental departments, as well as NGOs. These projects also focus on capacity building and the dissemination of information to increase the awareness of the potential problems and solutions, including SFM. It is also reported that the establishment of monitoring programmes to determine the current situation of forests and implementation of further research into future predictions of climate change, including extreme events, is an important measure for adaptation.

Mitigation Measures: Mitigation through afforestation, reforestation, agroforestry and sustainable land management is recognized within some NCs. Throughout the tropical domain, there are numerous reports of programmes and projects aimed at afforestation. Although the mitigation of climate change through carbon sequestration

tends not to be the primary objective of these projects, which are aimed more at environmental stability, they will result in an increase in carbon sequestration and carbon sinks.

Sub-Tropical Domain[2]

Observed Impacts: There has been an observed increase in climate variability in the southern Mediterranean region. This has resulted in an increase in dry periods and heavy rain events, and subsequently a decline of forest health and social impacts.

Vulnerabilities and Future Impacts: Forest ecosystems in the sub-tropical domain often occur in areas at the limits of growing conditions and, therefore, are highly vulnerable to modest climate changes. It is expected that sub-tropical forests will migrate poleward over the next 100 years in order to adapt to the changing climate. Overall, it is anticipated that the area of the sub-tropical forests will expand into the temperate domain, and the existing sub-tropical forests will shrink and lose in productivity. It is reported that migration is expected to be hampered by fragmentation and physical boundaries, such as cities, roads, mountains and agriculture.

Changes in the climate are predicted to increase the growth rates of forests as a result of extended growing periods. Higher growth rates might also increase instability of the ecosystem and thus increase vulnerability.

Throughout the sub-tropical domain an increase in extreme weather events and weather variability is anticipated. The number of heat waves occurring in the Mediterranean region during the summer months will continue. In addition, there is a predicted decrease in precipitation across the region, increasing the vulnerability to fire, and leading to general ecosystem degradation. The predominant causes of fire are through anthropogenic ignitions. An increase in such events is likely to increase the

[2] Sub-tropical countries include Annex I Countries which are contained within this region and have produced a NC are Australia, United States of America, Croatia, France, Greece, Italy, Japan, Monaco, New Zealand, Portugal, and Turkey. Non-Annex I countries include Argentina, Bahrain, Brazil, China, Mexico, Saudi Arabia, Turkmenistan, and Uruguay, and countries who developed a NAPA include Lesotho and Maldives

vulnerability to desertification, having detrimental impacts on social and economic wellbeing.

The social benefits of forests may be jeopardized through a loss of ecosystem services, such as soil protection and hydrological cycling. Furthermore, there is a risk of unemployment for those involved in the forest sector due to a loss of tree productivity.

Forest Management Measures: The migration of tree species poleward requires assistances by forest management. Reference is made to the following adaptation measures: high quality genetic selection or selection of trees from specific varieties/origins; promotion of mixed species forests; decrease of the area of monocultures; and reducing the threats of pests and diseases. It is also noted that forest management should focus on reducing stress from external sources, such as extreme events and disturbances. Forest models need to incorporate climate change so that management can be adjusted accordingly.

Policies for Adaptation and Instruments

Regulatory instruments: Policy tools for adaptation of forests to climate change are often specific regulations in the National Forestry Act, National Adaptation Strategy or equivalents. They are based on information about predicted impacts, vulnerabilities and adaptation options for climate change. In New Zealand responsibility is placed on the local authorities to adapt to and mitigate the impacts of climate change. It is specified who is responsible for incorporating adaptation into the planning process; ensuring adaptation is incorporated into long-tem planning. The Greek NC reports that measures will be taken in forestry to reduce the impact and vulnerability to desertification through afforestation, fire prevention, and improvements in forest health. Many countries promote adaptation by means of strengthening SFM and forest protection in the National Forest Act and environmental laws.

Economic instruments: Australia reports on a number of programmes which offer financial support for improving the environmental conditions. This includes tax incentives (deductions) for the expansion of plantations, and grants for environmental plantings. Similarly, New Zealand has a local afforestation programme which utilizes

financial incentives. Although these tools are not specifically aimed at increasing the adaptive capacity of forests, they can be viewed to achieving it.

Informational instruments: The dissemination of information on the impacts of climate change on forests, such as the increased susceptibility to fire events, is seen as crucial for anticipatory measures. National forest Acts, National Adaptation Strategy or equivalents are commonly used for dissemination of information pertaining to adaptation to climate change.

The Italian NC reports that through the introduction of a fire education programme the number of anthropogenic fires could be reduced. In Portugal, there have been leaflets distributed to the general public on methods on how to reduce the impact of drought, fire and heat waves, although this is not specific to the forest sector.

Mitigation Measures: The proposed mitigation measures comprise improved information of the forest actors about avoiding green house gas (GHG) emissions, increased use of wood products in new constructions, improvement of forest harvesting methods, afforestation, forest restoration, forest protection etc.

Temperate Domain[3]

Observed Impacts: Throughout the domain there have been observed increases in extreme climatic events and major disturbances including damaging storms, fire, and insect attack, all of which have been associated with climate change. The impacts include a decline in forest health, changes in species distribution and composition (increase in the area of deciduous at the cost of coniferous species), and decay of forest condition as a result of water stress. There are also some observed benefits in the forest sector that can be attributed to climate change. For example, in northern Italy where the mean annual temperature has increased and there is no water deficit, forests have expanded. Some countries report an increase in forest net primary

[3] Countries in the temperate domain which have submitted a NC are Australia, Austria, Belarus, Belgium, Bulgaria, Croatia, Czech, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Netherlands, New Zealand, Poland, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, and the United States of America. Non-Annex I countries are China and Turkmenistan.

productivity, increase in annual growth, and expansion of forest areas. However, the changes in forest growth rates cannot be separated into those caused by an increased growing season or CO^2 fertilization, and those caused by improved genetics and management. It cannot be excluded that increased growth may be negated by an increase in major disturbances, such as fire and detrimental storms.

Vulnerabilities and Future Impacts: The main vulnerabilities for forests are associated with alterations in the hydrological cycle, in particular through water shortages. This can occur directly through a decrease in precipitation, or indirectly as a result of increased temperature and the subsequent increase in evaporation or reduced snow melt. All forest types have the potential to be impacted by climate change in some form. In particular, artificial or "un-natural" stands, in regards to both species and species composition, e.g. monocultures are more vulnerable than forests which are in a more natural state, as are healthy forests compared to weaken or degraded ones. Temperate forests are predicted to change in forest composition due to a poleward shift of growing conditions. This will include an encroachment of the temperate into the boreal domain, and a loss of area with the expansion of the sub-tropical domain. This predicted poleward shift in climatic conditions over the next century is of the magnitude of 50-500km and 500m in altitude, however this rate is faster than many forests can migrate, and fragmented forests are not favourable for this. These changes will have ramifications on the ecosystem services provided by forests, and thus have social implications.

Climate change is predicted to increase growth rates due to longer growing periods, CO_2 fertilisation and increased efficiency in photosynthesis. Although an increase in extreme events and disturbances, including windstorms, fire, drought, insect and diseases, which are also predicted, may negate the benefits of climate change. Extreme events are expected to impact on forests in the short-term, what long-term impacts resulting from changes in the prevailing climatic conditions.

Lowlands and mountainous regions are most likely to be impacted on by climate change. Lowlands suffer from an increase of droughts and extended dry periods. In mountainous regions, species will migrate from the lower to the higher altitudes as the higher altitudes become suitable for regeneration. This includes an increase in the

tree-line by several hundred meters. Contrastingly, the high altitude alpine regions are vulnerable to extinction.

Although ecosystem services provided by forested areas are likely to be impacted by climate change as the structure and condition of forests change, they are not extensively addressed in the NCs reviewed for this report. There it is stated that the forests' ability to provide erosion protection, water purification, carbon sequestration, and recreation may be impacted.

Climate change may impact on the forest sector, through reduced timber yields caused by extreme events and disturbances, and a shorter winter harvesting period resulting from decreased ground freezing. Contrastingly, the predicted increased forest area and growth rates will benefit the forest industry.

Forest Management Measures: The management techniques outlined in the NCs are largely concerned with the formation of more stable forests in the face of climate change. Near-nature forest management and a move away from monocultures toward mixed forests types, in terms of both species and age classes, are advocated. In addition, natural or imitated natural regeneration is indicated as a method of maintaining genetic diversity. For the management against extreme disturbances improvements in fire detection and suppression techniques are recommended, as well as methods for combating pests and diseases. It is reported that through stricter quarantine and stricter sanitary management, the impact of insects and diseases can be minimized.

Policies for Adaptation and Instruments

The adaptation policy options identified in the NCs are largely concerned with increasing the resilience of forests to climate change, through forest expansion, SFM, and forest protection, although this is often a secondary impact of the policy, with mitigation being the more primary objective. The policies that were introduced concerning adaptation of forests and the forest sector often form parts of nfps or rural development programmes. However it is unclear from the NCs the depth of the information presented within these programmes, or if policy has been planned or implemented.

Regulatory instruments: Strengthening national forest laws or equivalent processes aiming at SFM, and subsequently adaptation, is commonly referred to throughout the NCs. This includes the protection of forests and forest genetics as well as the setting of performance guidelines for forest management. Also reported is in-situ-conservation and protective legislation against deforestation.

Economic instruments: Economic instruments, such as grants, subsidies, and compensatory payments, are used to promote afforestation, changes in species composition, and recovery from extreme disturbances. Voluntary forest certification systems such as FSC and PEFC are also used for providing financial incentives for SFM, and subsequently adaptation. In the Netherlands compensatory payments are made to landholders for contributions to water and ecosystem management under the ‘Green and Blue' imbursement scheme.

Informational instruments: A common mechanism for adaptation of forests to climate change is the nfp. It allows foresight in regards to the future climatic conditions, and therefore planned adaptation in addition to reactive adaptation. Furthermore, dissemination of information concerning the likely impacts of climate change, the economic and financial implications of adaptation measures, as well as guidelines for adaptation and assessing climate change impacts and adaptation options is portrayed as an invaluable instrument when dealing with climate change. The national strategies are supported by national monitoring and research programmes targeting at the impacts of climate change. Mapping of areas and forest types which are sensitive to climate change and carrying out risk assessments are also reported as adaptation options

Mitigation Measures: Throughout the NCs there is a trend to focus on mitigation measures for carbon sequestration as opposed to adaptation, although it is often difficult to separate the two. Thus, in many countries afforestation is promoted by financial incentives, and SFM and forest protection through regulatory measures.

Boreal Domain[4]

Observed Impacts: An increase in average temperature and precipitation has resulted in changes to plant physiology in this domain. Sweden reports that the sprouting and budding time and leaf fall have already altered, while growth rates and vegetation density have increased. There has also been a noted change in species distribution with an increase in altitude of some coniferous and deciduous forests in some parts of Sweden.

Vulnerabilities and Future Impacts: The boreal region is subject to similar impacts from climate change as other domains, with an increase in extreme events and disturbances, plant growth and changes in species composition. There could be an increase in growth rates of up to 40% over the coming century, with the biggest increases predicted for the northern forests. It is anticipated that the tree-line altitude will increase, and the boreal forest type will shift north-ward of 150 – 500 km over this century encroaching into tundra.

The boreal forests are reported to be highly vulnerable to increasing fire and insect damage as a result of climate change. Concerning the boreal forests of North America, it is anticipated that milder winters will prevail as the norm, reducing damage caused by heavy snow fall, however, increasing the over-wintering survival of damaging insects. The survival of damaging insects will inadvertently increase the volume of dead timber, thus increasing the likelihood of a fire event or pathogenic outbreak. Furthermore, there is an increased risk of windfall throughout the domain as a result of reduced ground freezing. Norway reports that all these negative impacts of climate change may reduce or negate the benefits from increased growth rates. Mountainous regions are sensitive to climate change as they have limited capacity for migration, and are likely to be impacted on by heavy snow fall.

The impact of climate change on the forest industry is uncertain. If the predicted growth rates are realized there would then be a subsequent increase in the amount of timber that could be sustainably cut. Additionally, there is a predicted increase in the

[4] Countries which have submitted a NC are Canada, Finland, Iceland, Norway, Russia, Sweden and the United States of America.

amount of hardwood that would be produced in regions where primarily softwood timber is produced.

Forest Management Measures: For the migration of species a migration corridor from south to north between fragmented landscapes is proposed. Finland promotes changes in species composition by creating more stable forests through replacement of spruce and pine by birch in the south. Various provinces of Canada have introduced climate change programmes for combating the increase in major disturbances, in particular to fire and insects.

To adapt to shorter winter harvesting periods as well as soft soils and roads, new harvesting techniques need to be developed which will better suit new conditions. Additionally, there will be a need to increase game management as a result of increasing population levels of large game, in particular moose.

Throughout Canada the introduction of prescribed burning is viewed as a viable option for reducing the risk of large scale fire events.

Policies for Adaptation and Instruments

A country's ability to adapt to climate change will largely depend on financial and human capacities. Consequently, it is the more developed regions which will be able to adapt with greater ease than less developed countries. As the boreal domain consists of comparatively few, well developed countries, there are good grounds for adaptation.

Informational instruments: Finland has launched a National Adaptation Strategy which also includes forestry. The proposed instruments aim at anticipatory and reactive policies of public administration and the private sector. The individual policies are indicated as immediate (2005–2010), short-term (2010–2030), and long-term (2030–2080). However, there was no specific mention of implemented policy concerned with the adaptation of forest to climate change. Under a similar premise to Finland, Norway and Canada reported to be developing a National Adaptation Strategy or equivalent. In addition, Canada has introduced provincial action plans and strategies for reducing the vulnerability to fire, including the introduction of

prescribed burning to alter fuel loads in forest. These initiatives have successfully reduced the area burned and the occurrence of large-scale fires.

Informational instruments prevail to promote adaptation in the boreal region. Finland reports high amounts of research into the impacts of climate change on forests and the forest sector, however a relatively low level into the adaptations to it. It also states that a lead time of 10 to 100 years is required for planning and implementing adaptive strategies for forests. Sweden has been working on a breeding programme aimed at developing trees that would be adapted to the predicted future climate.

The Canadian NC notes that the main aims for policy on adaptation are to raise awareness of adaptation; facilitate and strengthen capacity for coordinated action on adaptation; incorporate adaptation into policy and operations; promote and coordinate research on impacts and adaptation; support knowledge-sharing networks; and provide methods and tools for adaptation planning. These are similar aims as those identified by Finland.

Conclusions

Summarizing the information on existing policy tools for the adaptation of forests to impacts of climate change put down in the post 2004 NCs and NAPAs, the following observations can be made:

- Observed impacts of climate change have already been noted, with an increase in temperature, changes in precipitation, and an increase in the occurrence of extreme weather events and disturbances, resulting in regional forest degradation and changes in species composition and phenology.
- There is an anticipated change in forests and the forest sector as a result of climate change, with short-term impacts likely to be associated with extreme weather events and disturbances, and the longer-term impacts resulting from increased temperature and changes in precipitation.
- All forest domains are expected to experience a poleward shift in climatic conditions, varying from 100-500km, and up to 500m in altitude. Consequently, there will be changes in species composition. The most vulnerable forests are those with limited dispersal capacity, such as

mountainous species, degraded and stressed forests, or those located at the limits of ecological zones.

- The forests that are located in developing countries, in particular in the tropical domain, appear to be in more immediate danger from anthropogenic activities, which is predicted to be exacerbated by climate change. Pressure from deforestation and degradation from subsistence living, principally for agriculture and the collection of fuel wood, is a running theme throughout the reports from Non-Annex I countries.
- The majority of NCs and NAPAs were carried out by the ministries responsible for the environment and not by the ministries responsible for forestry.
- The NCs focus primarily on mitigation measures; adaptation of forests to climate change is secondary, NAPAs focus on reducing anthropogenic impacts on forests.
- The adaptation policies are often in the form of nfps with the principle objective of SFM, afforestation, and capacity building through education and increased awareness.
- It appears that options which incorporate autonomous adaptation, such as SFM, are favoured over anticipatory measures.
- The separation of mitigation from adaptation, in terms of forests and the forest sector, can be a superfluous task, as an action for one often intrinsically positively impacts the other.
- Multiple countries refer to a National Adaptation Plan, which is reported to contain adaptation options, or the need for such a programme to be developed, while specific adaptation options which have been implemented are scarcer.
- As a stand alone document, the information presented within individual NCs and NAPAs appears to be inadequate at the national level in terms of specific adaptation options available for forests and the forest sector.
- The reporting of adaptation policies vary considerably between countries, despite guidelines on the general format of the report.
- There are only a few distinctions made into immediate, short-term, medium-term, and long-term policies for adaptation of forests to climate change.
- In summary, the analysis indicates that there are programme deficits as result of reactive policy tools as opposed to anticipatory.

The mere existence of a policy programme or a policy instrument does not necessarily ensure that the expected result will actually be achieved; the outcome rather depends on the implementation process. Although the key instigators in this process are the implementation agency and the target group, many more participants intervene in the process and determine the final outcome which may more or less deviate from the expected result of the programme (“implementation deficit”). Presently, there is no information available about the national implementation outcomes of forest adaptation policies. In order to provide this, field research in each nation state would be necessary.

Full Report

1. Introduction

This report has been created for the Expert Panel on Adaptation of Forests to Climate Change established under the Joint Initiative on Forest Science and Technology of the Collaborative Partnership on Forests (CPF), and prepared under the direction and supervision of the International Union of Forest Research Organizations (IUFRO).

Forests are invaluable to the well being of terrestrial life. Although they only occupy approximately 30 per cent of the terrestrial sphere, they contain the majority of terrestrial biodiversity, and provide a plethora of ecosystem services which benefit the environmental, social and economic arenas. The sustainable management of this resource is of paramount importance for the continuation of ecosystem services for future generations. Sustainable forest management (SFM) involves the balanced management of forests, optimising the environmental, social and economic values for present and future generations. The predicted impacts of climate change have significant ramifications for forests and the forest sector, and will require changes in the management of forest ecosystems.

Over the past decade the issue of climate change has come to the forefront of scientific and governmental attention, resulting in the formation of conventions, forums and projects from local to global scales, as exemplified by the Joint Initiative on Forest Science and Technology of the Collaborative Partnership on Forests (CPF) (hereafter referred to as SciTech). SciTech is an activity of the CPF and is led by IUFRO.

Launched in April 2007, SciTech provides a global mechanism for effectively linking science and policy. It has been designed to support forest-related intergovernmental processes and conventions by assessing available scientific information in a comprehensive, interdisciplinary, objective, open and transparent way and by producing reports on forest-related issues of high concern, including emerging issues.

In this context SciTech aims at making a global contribution to the development of adaptation strategies, policies and measures for forests and the forest sector that are

based on the best knowledge available from multiple sources, in order to ensure SFM under climate change conditions. Subsequently in September 2007 SciTech established the Expert Panel on Adaptation of Forests to Climate Change, the first thematic panel to be established in the SciTech framework. It is the task of this Expert Panel to comprehensively assess the state-of-knowledge regarding the adaptation of forests to climate change. The assessment report to be prepared by the Expert Panel fits under the overall theme of "Forests in a Changing Environment" of the 8th session of the United Nations Forum on Forests (UNFF) scheduled to be held from April 20th until May 1st, 2009. It will also contribute significantly to the work of the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change.

This report details the key climate change impacts, vulnerabilities and existing policy and instruments related to forests and the forest sector, as identified at the national level. This is achieved through the review and analysis of specific national documents prepared for the United Nations Framework Convention on Climate Change (UNFCCC), specifically post 2004 National Communications (NC) and National Adaptation Programme of Action (NAPA). In total 95 national reports, equating to over 13,000 pages, were reviewed and incorporated into this report (Annex 4 – Incorporated Reports). Information regarding forests and the forest sector were collated and synthesised into ecological domains, and further delineated into Observed impacts; Vulnerabilities and future impacts; Management options for promoting adaptation; Policy, programmes and instruments for adaptation; and Mitigation measures.

Through specific analysis of the above mentioned national reports, this report aims to gather empirical evidence regarding existing policy promoting the adaptation of forests and the forest sector to climate change, and to determine policy and programme deficits. There are *programme deficits* if there are vulnerabilities of forests but no appropriate programmes (policy means) to adapt to them. *Policy implementation deficits* exist if the existing policy means are not appropriately implemented. Information presented within this report will directly contribute to Chapter III.2 Policy options for adaptation of the SciTech global assessment.

2. Methodology

The key terms of investigation in this report are vulnerability of forests by impacts of climate change; adaptation of forests to impacts of climate change; and mitigation of climate change by carbon sequestration of forests. In the following, the content of these terms is carried out in further detail.

Sub-tropical sclerophyllous plantation, South Africa

2.1 Key Terms

Vulnerability

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as “the degree to which a system is susceptible to, and unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its *sensitivity*, and its adaptive capacity”.

The vulnerability of a forest ecosystem to climate change is dependant on a number of factors. In general terms, natural forests which have a high diversity, at both the species and genetic level, large area and have a minimal disturbance regime, both natural and anthropogenic, are the least vulnerable to the adverse impacts of climate

change. Whilst the most vulnerable forest ecosystems are those which display the reverse characteristics and are considered to already be in a state of stress, at the limit of the growing conditions, or have specific growing conditions which will make migration difficult.

Furthermore, the impacts of forests, and their ability to adapt will largely depend on the anthropogenic impacts (both positive and negative), and countries where there is a high level of financial and human resources to assist adaptation will have reduced vulnerability.

Adaptation

The IPCC defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation:

Anticipatory adaptation – Adaptation that takes place before impacts of climate change are observed. Also referred to as proactive adaptation.

Autonomous adaptation – Adaptation that does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes in human systems. Also referred to as spontaneous adaptation.

Planned adaptation – Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state."

For this report, the instruments for the adaptation of forests to impacts of climate change will be delineated into the following three groups according to which media (authoritative power, money, and information) are used for their implementation:

- Regulatory policy instruments "comprises all those regulatory political interventions which formally influence social and economic action through blinding regulations" (Krott, 2005,)

- Economic policy instruments “are all those political means of intervention which formally influence social and economic action through the exchange of ‘economic values’” (Krott, 2005,)
- Informational policy instruments are “all those political means of intervention which formally influence social and economic action through information alone” (Krott, 2005,)

Mitigation

The IPCC defines mitigation as “an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks.”
Mitigation of climate change has been a major focus in the climate change debate over the past decades, and it is one of the objectives of the NCs to identify mitigation programmes and policies.

As greenhouse gases (GHGs), such as carbon dioxide (CO_2) is a major contributor to climate change, and forestry is one of the few sectors which can sequester carbon, forestry and the forest sector has an important role in the mitigation of human induced climate change. The NCs policy on mitigation can be delineated into four categories based on objectives:

- Increase carbon sequestration/carbon sink enhancement
- Sustainable forest management
- Forest protection
- Afforestation

Boreal, mixed coniferous/deciduous forests, Finland

2.2 Documents Analysed

This report utilises the national reports prepared for the UNFCCC, namely the NCs (NC) and national adaptation programmes of action (NAPA).

National Communications

Parties of the UNFCCC, here after referred to as the Convention, are required to submit national communications (NCs) on the implementation and progress to the Conference of Parties (COP). The Parties are divided into Annex I and Non-Annex I countries, depending on the level of commitment to reduction of greenhouse gasses (GHG):

Annex I NCs focus on the removal and emissions of (GHGs), and specific information on:

- National circumstances,
- GHG inventory and information,
- Policies and measures (related to GHG emissions and removal),
- Projection and assessment of policies and measures,
- Climate change impacts, vulnerability and adaptation,
- Financial resources and transfer of technology,
- Research and systematic observations, and
- Education, training and public awareness

While non-Annex I countries were required to report using a similar structure, with more focus on the linkages between climate change and sustainable development.
Signatories of the Convention are expected to produced and released NCs according to a predetermined schedule, differing between Annex I and Non-Annex I countries. As such, the number of released NCs varies from country to country, ranging from one to four.

National Adaptation Programmes of Action

The national adaptation programmes of action (NAPA) is a process that was formulated for least developed countries (LDCs) and identifies priority activities, which without vulnerability to climate change would increase and result in higher future costs. The NAPA incorporates existing strategies for coping with climate variability, rather than focusing on scenario-based modelling to gauge future

vulnerability and state level long-term policies. It also focuses on action based, country specific initiatives, with the objective of being understandable and of use to decision makers and the general public.

2.3 Criteria for analysis

For the purpose of this report analysis of a subset NCs and NAPAs was carried out, utilising the release date and recency within the report series as a predetermined distinguisher. As a consequence, the most recent NCs and NAPAs of the national series, which were released post 2004 were analysed[5]. This resulted in the analysis of 95 national reports, of a possible 282, including 41 Annex I NCs, 23 Non-Annex I NCs, and 31 NAPAs.

The year 2004 was determined to be the optimal cut-off period for inclusion of reports, as this incorporated all Annex I NCs and NAPAs, as well as the Non-Annex I NCs from most of the countries which have significant forested area, such as China and Brazil.

Information contained within the analysed reports was extracted utilising a multi-tiered prestructred case and further delineated with pattern coding.

The preliminary separation of the national reports was into ecological *domains*, as described by the United Nations Food and Agriculture Organisation (FAO) global forest classification, and agreed upon by the Expert Panel as a framework for delineation. The Global Forest Resource Assessment (FRA), produced by the FAO (2001a), includes a Global Ecological Zoning (GEZ) map and dataset, incorporating global ecofloristic zones into a global forest classification. Global Ecological Zones with similar overarching climatic conditions were clustered into thematic groups, known as domains. Through this, the *Tropical, Sub-Tropical, Temperate, Boreal,* and *Polar* domains were delineated (Figure 0-1 Distribution of the world's forests by major ecological zone as published in the 2000 FAO FRA (FAO, 2001b).

[5] With the exception of Bulgaria, where if was stated that the needed information was presented in an earlier NC, and not included in the most recent publication. In this circumstance the earlier NCs were also reviewed.

Using the GEZ map coupled with a world map, it was possible to allocate countries to a particular, or multiple domains. In the circumstances where a country crossed domains boundaries, relevant information was presented in both domain chapters.

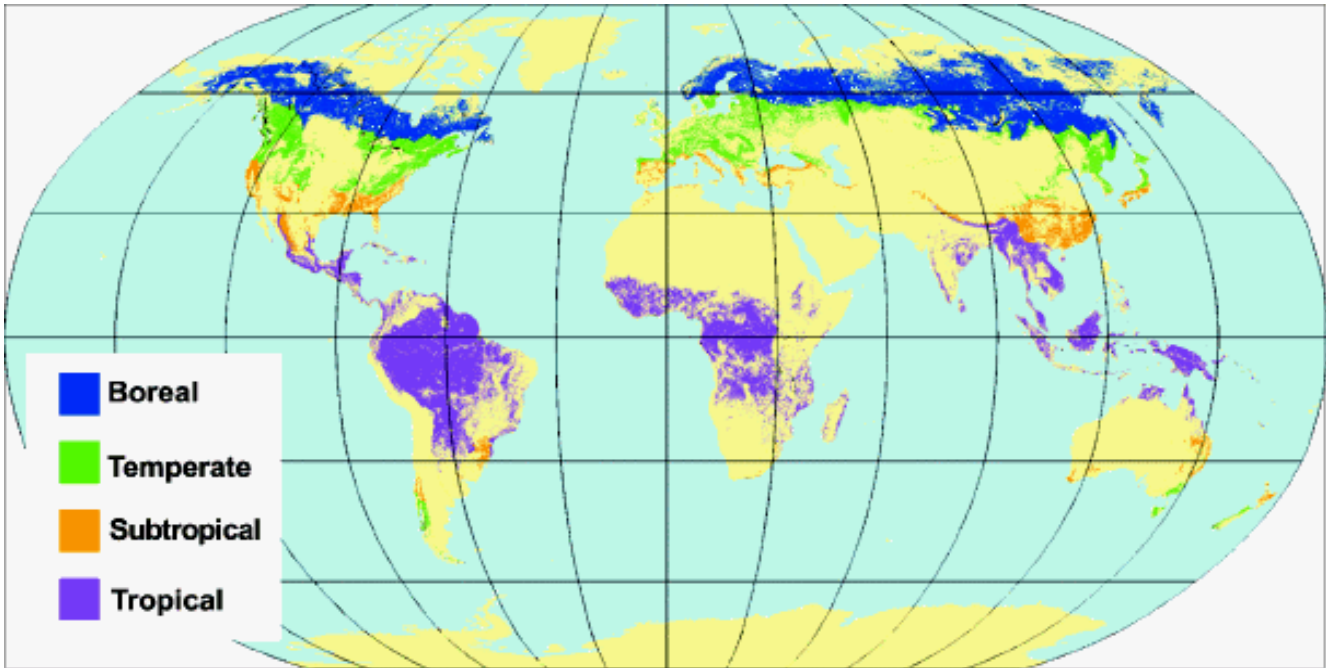


Figure 0-1 Distribution of the world's forests by major ecological zone as published in the 2000 FAO FRA (FAO, 2001b).

Following domain separation, the national reports were analysed for content related to forests and the forest sector. This was achieved through careful analysis of pertinent chapters within the national reports (e.g. The “Policy and Measures”, “Impacts and Vulnerabilities” chapters of NCs), coupled with word searches (e.g. Forest, Forestry, Afforestation, Tree, Ecosystem, Timber/wood). By this means, it was possible to identify the relevant information.

Once the core information relating to forests and the forest sector was extracted, the information was clustered under five pre-structured thematic groups:

- ***Observed impacts*** - Assumed to be any event or activities which were reported to already have occurred or are occurring, and are related to climate and climate change. E.g. observed increase in forest fires.

- ***Vulnerabilities and future impacts*** **-** Assumed to be any vulnerability, or event which is predicted to occur as a result of climate change E.g. predicted increase in the occurrence of forest fires as a result of climate change.
- ***Forest management measures*** **–** Assumed to be any measure which involves direct forest management, E.g. afforestation with fast growing species
- ***Policies for adaptation and instruments*** **–** Assumed to be any policy, existing or proposed, which will influence the adaptation of forests and the forest sector to climate change. Also included are adaptation options which would require policy formation for implementation E.g. promotion of SFM. As mentioned, this group is further separated into regulatory, economic and informational instruments.
- ***Mitigation Measures*** **–** Assumed to be any measure which mitigates climate change. E.g. increases carbon sequestration. Notably, mitigation activities which double as an adaptation option are only briefly mentioned within this group, and mostly covered under adaptation options.

During the allocation and analysis of information into each of the five groups, pattern coding was used to further separate information into more specific sub-categories. This was particularly relevant for *vulnerabilities and future impacts*, where information was partitioned into key thematic sub-groups:

- ***General Vulnerability*** – When a forest is vulnerable to climate change, but a specific threat is not specified, it was clustered in this group.
- ***Topographic Delineation*** – When topographic delineation is specified, (i.e. coastal, lowland, mountainous forests), it was incorporated into this group.
- ***Physiological Changes*** – When changes in the physiological state of forest plants and forests are predicted as a result of climate change they are included in this group (i.e. phenological changes, change in species composition).
- ***Extreme Events and Disturbances*** – When a short lived event which has considerable impacts on forests is specified, such as fire, drought, storms, insects, disease, etc. it was clustered in this group.
- ***Social Impacts*** – When it was reported that changes in forests had a direct impact on the social arena, it was separated into this group.

Through the above mentioned process, it was possible to extract and collate the information presented within the analysed reports.

2.4 Limitations of the Study

The national reports analysed within this report were created from a national perspective. As such, the combination and up-scaling of national reports to a domain level limits the level of detail that can be obtained for specific impacts and vulnerabilities. Additionally, there are discrepancies in the information available for each domain, with significantly more information on the temperate and tropical domain, in comparison to the sub-tropic and boreal domains. This likely reflects the differences in the number of analysed national reports representing each domain. The tropical domain included 49 national reports, temperate included 37, while sub-tropical included 21 and boreal just 6, with 14 countries falling under multiple domains. This variation in the quantity in information suggests that any one national report is not indicative of entire domain.

Additionally, countries which cross domain boundaries do not always separate the predicted impacts into forest types, in particular when discussing adaptation options, rather tending to treat forests as a single entity. As such, accuracy of the separation of the information presented into domains may be limited.

Not all national reports were analysed in the formation of this report, however those included are believed to be sufficient to provide the necessary information. Furthermore, only one of a series of national reports was analysed, for example, a countries 4th NC, but not the 1st, 2nd or 3rd. As these national reports are prepared as a series, it is possible that information contained within an earlier report is not presented again in the more recent report. However, it is not possible to determine if this is because of a change in circumstances or an attempt not to repeat information.

Differentiation between climate change and other climatic anomalies, such as the El Niño Southern Oscillation (ENSO), is difficult, as in some countries it causes similar impacts as predicted under climate change, such as Venezuela, Brazil, Australia,

Ethiopia. However, as these events are predicted to be impacted by climate change, the incorporation of the impacts from these events into the report was considered valid.

The delineation between mitigation and adaptation can at times be difficult to define. This is due to the similarities between the two in the context of forests and the forest sector. Often, the actions in one will positively benefit the other. For example, afforestation increases the amount of carbon sequestration, and also aids in stabilising ecosystems and/or reduces pressure on existing forests, thus promoting autonomous adaptation. Similarly the separation of policy which is produced for adaptation from policy which inadvertently promotes adaptation can be equally challenging. Consequently, policy which has been implemented for mitigation may inadvertently promote adaptation. For example, policy promoting SFM with the objective of increasing carbon sequestration will also increase the resilience of the forest, and thus the adaptive capacity of it. For the purpose of this report, in situations such as this, the information is assumed to be an adaptation option, rather than mitigation.

The definition of ‘SFM’ is not provided by the UNFCCC. As such it is not possible to determine if references to SFM made within the national reports assumes business as is, or a more holistic and adaptive approach to forest management, incorporating adaptation to climate change.

Despite best efforts to include all relevant information pertaining to the impacts, vulnerabilities and adaptation options of forests and the forest sector to climate change, as stated with the national reports, since this is a synthesis of information, it is not possible to include all information at the same level of detail as described within the analysed reports. Additionally, it is possible that the circumstances have changed since the release of the analysed national reports.

Although there are limitations in this report, overall, they are not believed to significantly detract from the information presented within this report or the key findings.

3. Global Review

The following chapter details the information contained with the in NCs and NAPAs, as delineated into the four domains, *tropical*, *sub-tropical*, *temperate*, and *boreal*, as defined by the FAO FRA (2000).

3.1 Tropical Domain

The Tropical domain is characterised by climatic conditions where the mean temperature of all months is over 18^{o}C. It is located approximately between the Tropic of Cancer 23^{o} N and the Tropic of Capricorn 23^{o} S, which equates to being located between the sub-tropical domain. The lowland zones are up to 1000 - 1500 meters. The tropical domain is delineated into six GEZ, namely:

- Tropical rain forest
- Tropical moist deciduous forest
- Tropical dry forest
- Tropical shrubland
- Tropical desert
- Tropical mountain systems

The tropical domain vegetation is highly variable, with forests ranging from dense evergreen /semi-evergreen rainforest, to deciduous woodlands and arid deserts. The tropical GEZs cover approximately 57.5 million km^{2}. 49 reports from countries in the tropical domain were analysed, with the Annex I countries which are reported as having tropical forests and have prepared a NC are Australia and the United States of America, with Non-Annex I countries being Brazil, Cameroon, Fiji, Gabon, Guinea-Bissau, India, Madagascar, Mexico, Nepal, Rwanda, Saudi Arabia, Sierra Leone, Sao Tome and Principe, Solomon Islands, Suriname, Tonga, Turkmenistan, United Arab Emirates, Venezuela while countries who produced a NAPA include; Benin, Burkina Faso, Djibouti, Guinea, Haiti, Madagascar, Mali, Democratic Republic of Congo, Senegal, Bangladesh, Bhutan, Burundi, Cambodia, Cape Verde, Comoros, Eritrea, Guinea-Bissau, Kiribati, Malawi, Mauritania, Niger, Rwanda, Samoa, Sao Tome and Principe, Sudan, Tanzania, Tuvalu, Vanuatu, Zambia.

3.1.1 Observed Impacts

The impacts of climate change on forests and the forest sector have been observed in the tropical domain (NAPA – Comoros, Niger, Guinea-Bissau, Samoa, Burundi, Eritrea, S. Tome & Principe, Kiribati, Solomon Islands, Tanzania; NC – India, Saudi Arabia). This includes an increase in the average temperature (NAPA – S. Tome & Principe, Guinea-Bissau, Kiribati, Eritrea; NC – Nepal, Saudi Arabia).

In central Africa, there has been observed changes to terrestrial ecosystems linked to climate change driven processes, for example aridity and soil degradation (NAPA – Burundi, Djibouti). In the more arid areas of the tropical domain, such as northern Africa, there has been a noted increase in temperature, and subsequently a decrease available plant based products (NAPA – Eritrea). This has had social implications, as communities in the domain often depend on forests for fuel-wood, construction, food and fodder (NAPA – Eritrea). Also in these regions forests and the economies that depend on them have also been detrimentally impacted by climatic events such as floods, droughts, sand storms, heat waves, insect attack and fire (NAPA – Niger).

Driven by prolonged dry periods and higher temperatures there has been an observed expansion of savannas and shrublands, as well as a general degradation of forested areas in some regions of the tropical domain (NAPA – Guinea-Bissau, Niger, S. Tome & Principe, Kiribati). This trend may be worsened by an observed decrease in precipitation (NAPA – Comoros).

The Comoros NAPA reports that as a result of land degradation, which is exacerbated by climate change, forest ecosystems have been negatively impacted, and consequently 160ha a year of forest disappears. Likewise, Niger reports that due to severe droughts, coupled with human activities, approximately 338,180 ha of forested land has been lost since mid last century.

There has also been an observed increase in extreme weather events, such as cyclones, storms, and droughts having detrimental impacts on forests (NAPA – Comoros, Niger, Guinea-Bissau, Guinea, Djibouti, Samoa, Uganda). An increased frequency of drought conditions has resulted in an increase in fire events in some areas of the

tropical domain, leading to changes in forest composition and forest degradation (NAPA – Samoa, Tanzania).

Furthermore, degradation of coastal forests as a result of changes in the hydrological regime, such as rises in the sea level and water shortages, have been recorded (NAPA – Kiribati). Additionally coastal areas have been inundated by storm surges, flooding and high tides associated with cyclones (NAPA – Solomon Islands).

Mountainous regions have also experienced an increase in landslides as a result of climate change and deforestation (NAPA – S. Tome & Principe; NC – Nepal)

There has also been significant dieback of some forest species which has been linked to changes in the climatic conditions, for example the Juniper in Saudi Arabia. However, climate change is reported as only being one of many factors that caused the dieback (NC – Saudi Arabia). Also included were anthropogenic stresses and the natural lifecycle of the species (NC – Saudi Arabia). In other regions of the domain there has also been an observed increase in pests and pathogens (NAPA - Tanzania). Although in some regions tree growth has been hampered, in other regions of the domain there has been an observed increase in Net Primary Productivity (NPP) (NC – India).

The observed loss of medicinal plant species as a result of anthropogenic activities and severe drought was reported as an impact on the forest sector (NAPA – Uganda). This has severe consequences for the rural communities which depend on these species for cures of ailments (NAPA – Uganda).

3.1.2 Vulnerabilities and Future Impacts

3.1.2.1 General Vulnerability

The tropical domain is predicted to experience an increase in temperature, with an overall decrease in precipitation, although this may differ between regions (e.g. mountainous regions and regions with bimodal rainfall patterns) (NAPA – Tanzania, Burkina Faso; NC – India, Nepal, Sierra Leone, United Arab Emirates, Mexico). Although precipitation models are reported as having a high level of uncertainty (NC – India, United Arab Emirates), for example the United Arab Emirates reports a predicted change in annual rainfall of -10.5% ± 32.5% (NC – United Arab Emirates). Although rainfall may decrease, an increase in the magnitude of rainfall events is anticipated in some regions (NAPA – Bangladesh, S. Tome & Principe, D.R. Congo; NC – Nepal). As vegetation type and amount is relative to temperature and rainfall, tropical forests are vulnerable to climate change (NAPA – Zambia, Burundi; NC – Australia, Nepal, Saudi Arabia, Sierra Leone, Guinea Bissau).

The most vulnerable forest species are those which have a limited geographic range, poor dispersal capacity, are drought sensitive and have poor regeneration rates (NAPA – Tanzania; NC - Australia). Moreover, the forest types that are already at the limits of growing conditions, such as in the arid regions, are likely to be the first to exhibit the impacts to climate change (NC - United Arab Emirates).

Vulnerability is intrinsically linked with adaptive capacity, which can be significantly hampered by limitations in financial and human resources (NAPA – Cape Verde, Malawi, S. Tome & Principe; NC – Brazil, India, Nepal, Venezuela). As a significant proportion of the forests in the tropical domain are located in countries with a developing economy with more limited financial resources, this may have significant ramifications on the vulnerability of the domain to climate change, as these countries have restricted means to respond to change (NAPA – Cape Verde, Malawi, NC – Brazil, India, Nepal).

Furthermore, many of the forests located in the tropical domain are currently being degraded, deforested and exploited through anthropogenic activities which has

inherently weakened the forests resilience to climate change (NAPA – Burundi, Bangladesh, Benin, Ethiopia, Kiribati, Guinea, Mali, Comoros, Mauritania, S. Tome & Principe, Tanzania, Vanuatu, Uganda, Sudan; NC – Nepal, India, Rwanda, Saudi Arabia, Sierra Leone, Guinea-Bissau, Venezuela, Mexico).

Of particular relevance to the tropical domain is deforestation, both legal and illegal, largely at the benefit of agricultural lands, but also for the collection of timber and non-timber resources (NAPA – Benin, Cambodia, Cape Verde, Comoros, Ethiopia, Guinea-Bissau, Guinea, Uganda, Zambia; NC – Brazil, Fiji, Nepal, Rwanda, Saudi Arabia, Sierra Leone, Madagascar, Venezuela). Deforestation has significant implications in relation to climate change as decreased area and fragmentation increases vulnerability to climate change (NC – Nepal, India, Saudi Arabia), as well as acts as a major source to CO_2 emissions (through burning, lost soils stores and sink potential) and significantly reduces the adaptive capacity of forests and communities (NC – Brazil). In addition deforestation leads to a loss of ecosystem services, such as watershed and soil protection, which will have detrimental effects on the social arena (NC – Solomon Islands, Madagascar).

It is predicted that deforestation and forest degradation will result in the extinction of critically endangered species, and significant degradation of species which are currently in a vulnerable state (NC – Saudi Arabia).

As mentioned, forests in a degraded state are more vulnerable to climate change than those in a healthy condition. The drivers of forest degradation are often for subsistence purposes, such as building materials, food and fuel wood (NAPA – Benin, Comoros, Brazil, Malawi, Kiribati, Sudan, Tanzania, Guinea, Mali, Djibouti; NC – Brazil, India, Nepal, Rwanda, Guinea-Bissau). This degradation has been exacerbated though increasing population pressure, and has resulted in the degradation of formally protected forests, increasing forests vulnerability to climate change (NAPA – Burundi; NC – Brazil, Nepal). Although traditionally fuel wood consisted of deadwood, in countries where there has been a progressively urbanised population and expansion of coal fuelled heating systems, growing forests have been increasingly targeted to meet the demands, leading to further forest degradation (NAPA – Mauritania, Sudan, Tanzania, Zambia; NC - Sierra Leone, Brazil).

It is also reported that land insecurity has led to poor land management, as insecurity does not support long term investments (NAPA – Comoros). Additionally, forests are at risk due to a lack of environmental education (NAPA – S. Tome & Principe).

In summation, many of the forests in the tropical domain are in a fragile state in countries with limited socio-economic resources for adaptation, thus highly vulnerable to climate change.

3.1.2.2 Topographic Delineation

Coastal Areas

Coastal forests, such as mangroves, are important stabilisers in coastal environments, contributing to the prevention of coastal erosion (NC - Sierra Leone, Tonga). However, these coastal ecosystems are vulnerable to the impacts of extreme weather events, in particular to ocean surges (i.e. tsunamis), cyclones, as well as inundation due to increased sea levels (NAPA – Bhutan, Cambodia, Kiribati, Madagascar, Tuvalu, Senegal; NC – Fiji, Saudi Arabia, Solomon Islands, Suriname, United Arab Emirates, Brazil). Events such as these are anticipated to increase coastal erosion (NAPA - Kiribati, Tuvalu; NC – Saudi Arabia).

Mangrove forests are highly vulnerable to the impacts of climate change, in particular from increased soil salinity as a result of increased evapotranspiration and low water flow during winter (NAPA – Bangladesh, Senegal). Similarly, in other regions of the tropical domain mangroves are at risk due to inundation, and changes in nutrient accumulation and sedimentation (NC – Saudi Arabia, Suriname; NAPA - Cambodia). Mangrove forests may also be at risk of deforestation for agriculture and aquaculture (NAPA - Guinea-Bissau; NC - Suriname, Tonga).

Mountains

In general the delineation of mountain forests when discussing vulnerability was limited to a few countries (NAPA – Bhutan, Tanzania, S. Tome & Principe; NC – Nepal). However, in Bhutan (NAPA), forest ecosystems and alpine range lands are reported as vulnerable to biodiversity degradation and a reduction in area as a result of drought induced fire, changes in phonological characteristics of plants, and loss in

endemic species. Mountainous forests can also be vulnerable to climate change due to the diversity of the forest structure, where by there are multiple niches occupied by differing forest types, effectively creating isolated islands (NC – Saudi Arabia). Mountainous forests of Tanzania are at risk of biodiversity loss as a result of increasing fire events associated with climate change (NAPA – Tanzania), and at risk from landslides from torrential rainfall in S. Tome & Principe (NAPA – S. Tome & Principe).

3.1.2.3 Physiological Changes

Change in Growth Rates and Composition

The information presented on changes in growth rates and species composition was comparatively less than that presented for other domains. However, climate change is anticipated to impact on species composition and structure of forests within the tropical domain (NAPA.- Burundi, Ethiopia, Tanzania, Uganda; NC – Nepal, India, Saudi Arabia, Sierra Leone). It is predicted that there will be a poleward and upward (up to 500m in elevation) migration of forest types as a result of climate change (NC – India, Nepal). For example, 70 per cent of the forest types in India are predicted to change in forest structure and species composition as a result of climate change (NC – India). As the rate of change is predicted to exceed some plants ability to migrate and different plants have different migration rates (i.e. all forest species will not simultaneously migrate), it is expected that there will be significant changes in the level of biodiversity, and there is a chance of local extinctions (NAPA – Uganda; NC – India). Given the high complexity of forest ecosystems, the loss of one species may result in the loss of others, creating a 'domino effect' (NC – India).

It is noted that migration of forest species may be inhibited due to changes in the forest landscape and a lack of connectivity between forests (i.e. fragmentation), as well as natural barriers such as mountains and deserts (NC – Saudi Arabia, India).

In general terms, in areas where rainfall is predicted to decrease, the species composition will change in favour of dry forests, woodlands and savannas and a decrease in the vegetative biomass, whilst in the regions where rainfall is expected to increase it is expected that there will be a shift to moist/wet forests and an increase in the vegetative biomass (NAPA – Burundi, Ethiopia, Tanzania, Guinea; NC – India,

Sierra Leone). Climate change is also predicted to alter the age class distribution of forests, with an increase in younger trees (NC – Saudi Arabia).

The growth rates and the growing season of tropical forest species are expected to alter as a result of increased temperatures and the occurrence of strong rainfall events (NAPA – Burundi, Bangladesh, Zambia; NC – India). In addition, regeneration of some forest species is anticipated to be impeded by drought (NAPA – Burundi, Zambia), and be further hampered by the lack of vectors for seed and pollen dispersal (NC – Saudi Arabia), and forest degradation (NC – India)

In regions where an increase in precipitation is predicted, there is a likely increase in forest growth and NPP and a shift in composition due to enhanced water availability (NC – India). However, in areas which are predicted to experience increased water erosion from torrential rainfall, a decrease in growth rates might also occur due to a decrease in available nutrients (NAPA – Bangladesh). This decrease may be exacerbated as a result of higher evapotranspiration during the winter period.

Climate change is also anticipated to induce phenological changes (NAPA – Bhutan; NC – Saudi Arabia, India) such as trees shedding leaves at earlier times and alterations in fruit maturation (NC – Saudi Arabia). Due to changes in CO_2 and nitrogen levels it is anticipated that species which exhibit high plasticity and adaptive capacity, such as invasive species, will become dominant over time (NC - Saudi Arabia).

Genetic Degradation

It is reported that due to anthropogenic pressures and changes in the climate, there has been a loss of biodiversity in some countries (NAPA – Kiribati; NC – Saudi Arabia). Subsequently these forests are at risk of genetic degradation, as exemplified by some food trees in Kiribati which are vulnerable to a loss of genetic diversity, and subsequently food quality is also at risk (NAPA – Kiribati). A loss in genetic diversity will increase the vulnerability of forests to climate change (NC – Saudi Arabia).

3.1.2.4 Extreme Events and Disturbances

The tropical domain is predicted to experience an increase in extreme weather events and disturbances, including drought, fire, wind, floods, landslides, pests and diseases (NAPA – Malawi, Bhutan, Bangladesh, Kiribati, Cambodia, Samoa, S. Tome & Principe, Tanzania, Nigeria, Uganda, Zambia; NC – Rwanda, Brazil, Saudi Arabia, Venezuela).

An increase in temperature and lengthening of the dry season as a result of climate change is expected to exacerbate existing stress on forest ecosystems (NAPA – Malawi, S. Tome & Principe, Tanzania; NC - Nepal). Subsequently, an increase in the occurrence of drought is a significant concern for many of the countries in the tropical domain (NAPA – Malawi, Bangladesh, Kiribati, Cambodia, Samoa, Zambia; NC – Rwanda, Saudi Arabia). An increase in drought is predicted to lead to changes in species composition, and to decreased biodiversity, soil quality and forest health (NAPA – Malawi, Zambia; NC – Saudi Arabia). Consequently, there is also an inherent vulnerability to fire events existing in this domain (NAPA – Bhutan, Burundi, Kiribati, Malawi, Rwanda, Tanzania, Samoa, Zambia; NC – Venezuela, Saudi Arabia, Rwanda, Mexico). An increase in the frequency of fires is likely to have detrimental impacts on forest health, and increase vulnerability to climate change. (NAPA – Uganda; NC –Sierra Leone, Mexico)

It is predicted that there will be an increase in the torrential rainfall events during the wet season, and subsequently and increase of runoff (NAPA – Bangladesh, S. Tome & Principe) resulting in an increased probability of flooding (NAPA – Malawi). An increase in rainfall is also predicted to decrease the water absorbed by the soil, and increase the erosion of forested areas (NAPA – Bangladesh). Forests that are less densely stocked are more vulnerable to water erosion than forests which have dense tree coverage.

Poor forest management and deforestation is anticipated to increase the likelihood and severity of floods (NAPA – Cambodia, Uganda) and landslides (NC – Nepal, Uganda). As a result of such extreme events it is predicted that there will be an increase in the threat of pests and diseases (NAPA – Samoa; NC – Saudi Arabia). This problem may be exacerbated through the predicted expansion of the geographic

range of pests and pathogens (NC – Saudi Arabia). Plantation monocultures are reported to be more vulnerable to pests and diseases (NC – India).

3.1.2.5 Social Impacts

An overriding issue throughout the NAPAs and NCs was that many countries in the tropical region have a low GDP per capita and a high percentage of their population exerting pressure on the national environment for subsistence, in particular on forests for the collection of fuel wood (NAPA – Kiribati, Bangladesh, Eithiopia, Guinea-Bissau, Mauritania, Niger, S. Tome & Principe Vanuatu, Sudan, Uganda, Zambia; NC – India, Nepal, Sierra Leone, Suriname, Tonga, Guinea-Bissau). Fuelwood accounts for more than 80% of wood consumption in Guinea Bissau (NC – Guinea Bissau). Forests account for 40% of the India's energy needs (NC – India), and 95% of the domestic energy needs for Sierra Leon (NC – Sierra Leon).

Climate change is predicted to exacerbate the existing anthropogenic stress on forest ecosystems (NAPA – Kiribati, Bangladesh, Tanzania; NC – India, Nepal). Subsequently it is predicated that there will be an increase in social problems and poverty (i.e. lack of food, fuel wood, and building materials) (NAPA – Kiribati, Tanzania, Zambia; NC - India), which again increases stress on the natural environment as the population attempts to meet their living requirements, thus forming a cycle of social and environmental degradation (NAPA – Kiribati; NC - India).

It is reported that woman and children, as the predominant collector of fuel-wood, are likely to be the most impacted by loss of forests as they will be required to travel further distances (NAPA – Zambia). Communities may experience further hardship as climate change may impact on the food trees, such as coconut and bread fruit, through the extended dry periods (NAPA – Kiribati).

The economies of forest dependant communities are vulnerable due to the impacts of climate change (NAPA – Samoa). This may have significant social implications as in India alone an estimated 200 million people depend on forests for their livelihood

(NC – India). Niger reports that 87% of the population work in the rural sector, and 6.2% of the GDP comes from forestry and fisheries (NAPA – Niger).

Impacts of climate change are not confined to tangibles. It is also reported that communities which have strong cultural bonds with the environment are vulnerable to loss of cultural heritage due to forest degradation (NAPA –Samoa, Vanuatu).

3.1.2.6 Summary of Vulnerabilities and Future Impacts

The tropical domain is predicted to experience an increase in temperature and changes in precipitation, having consequences for the forests of the domain. The most vulnerable forests will be those which are located at the limits of growing conditions, with poor dispersal, and low genetic diversity.

The forests of the tropical domain are currently under pressure from anthropogenic activities which are leading to deforestation and forest degradation. This includes the conversion of forested land for agriculture, and unsustainable removal of timber for fuelwood and building materials. The social pressures being placed on these forests cannot be understated, nor can the value of the forests for those who depend on them.

It is predicted that climate change will exacerbate the existing stresses on the forest ecosystems, resulting in further forest degradation. Extreme events and disturbances associated with climate change, such as drought, fire, floods, and insect attacks are predicted to increase, causing damage to forests.

The coastal mangrove forests are predicted to be degraded by ocean surges, inundation and salinity, while mountainous species are at risk because of a limited ability to migrate and an increase in major disturbances.

Changes in the prevailing climatic conditions are anticipated to cause a poleward shift in forest species composition, and a migration from lower to higher altitudes. In regions where precipitation decreases it is expected that vegetation density will also decrease, while it will increase in areas where precipitation increases.

Given the speed at which the climate is predicted to change, it is expected that many species will not have the capacity to migrate or adapt fast enough to avoid damage, or in some circumstances, extinction. The loss of ecosystem services associated with forest degradation would have detrimental impacts on those who depend on forests. In the tropical domain, this is a significant number of people, with more than 200 million directly dependant on forests in India alone. Women and children will be the most impacted by forest degradation as they are required to walk further for fuelwood.

Tropical rainforests, Brazil

3.1.3 Management for Adaptation

The utilisation of community based forest management aimed at promoting afforestation and the conservation of land, water and timber resources is reported within many of the analysed reports (NAPA – Bhutan, Ethiopia, Cambodia, Samoa, Tuvalu, Vanuatu, Tanzania, Zambia; NC – Fiji, Nepal, Rwanda, Sierra Leone). Included in this is the introduction of fast growing tree species that will be more resilient to possible disturbances, such as insect, disease and fire (NAPA – Bhutan, Burundi, Eritrea, Samoa, Tanzania; NC - Sierra Leone). Through the utilisation of short rotation species and management practices it is reported that forests will have an enhanced resilience to climate change (NC – India).

Anticipatory afforestation accounting for latitudinal and altitudinal gradients and utilising species which will be better suited to the future climate are also promoted (NC – India, Sierra Leone). Without appropriate management, such as anticipatory planting, it is reported that the many species would be unable to match the rate of change predicted for the climate (NAPA – Uganda).

The tropical domain has a history of being frequently impacted by severe weather events, such as floods, droughts, cyclones and storms (NAPA – Bangladesh, Comoros, Kiribati, Mozambique). Consequently there are a number of programmes and initiatives that exist to mitigate the impacts of these events. These include the construction of cyclone and flood shelters, coastal embankments against ocean surges, and drainage channels (NAPA – Bangladesh). Similarly, community based afforestation programmes are promoted as a method of reducing the vulnerability to floods (from both heavy rainfall and glacial melt) (NAPA – Bhutan, Cambodia).

An adaptation option identified to cope with the potential increase in fire events is to promote community based fire prevention projects, including equipping and training villages (NAPA – Bhutan, Guinea, Madagascar, Malawi, Samoa, Tanzania, Zambia).

Community based programmes concerned with the restoration and protection of mangroves are mentioned in various national reports (NAPA – Bangladesh, Cambodia, Samoa, Tuvalu, Tanzania, Vanuatu). The Tuvalu NAPA reports that the

establishment of a protective forested belt along coastal areas to prevent damage from storm surges and cyclones is a high priority. Again, this is reported to be best carried out as a community based project (NAPA – Tuvalu). Similarly other countries report mangrove afforestation for the prevention of damage to coastal zones (NAPA – Vanuatu, Senegal; NC - United Arab Emirates, India).

SFM is also reported as a method of increasing the resilience of forests to climate change (NC – India, Madagascar).

Changes in forest management, such as harvesting and planting dates, and utilisation of thinning are possible methods of adapting to climate change (NC - Sierra Leone). It is also reported that forest harvesting should be limited by the capacity to regenerate and overall there is a need for the promotion of reforestation (NAPA – Mauritania, Samoa, S. Tome & Principe).

Various reports promote changes in the utilisation of forests, such as the diversification of construction materials, including the use of non-timber products, as well as the promotion of non-wood fuels (NAPA - Mauritania, Eritrea, Rwanda, S. Tome & Principe, Sudan, Tanzania; NC – Nepal, Rwanda, Solomon Islands, Suriname).

Tropical rainforests, Brazil

3.1.4 Policies for Adaptation and Instruments

The acceptance of damage caused by climate change does not equate to adapting to it (NAPA – Cambodia), as such it is important that actions be taken to minimise the detrimental impacts of a changing climate. It is also recognised that environmental policy needs to be developed which incorporates climate change, including sufficient flexibility to react to possible impacts of climate change (NAPA – Kiribati). The Indian NC typifies much of the vulnerabilities and associated policy and programmes being implemented in the tropical domain (Box 1).

A significant inhibitor of adaptation for many of the countries located in the tropical domain is insufficient financial and human resources to create and implement policy, programmes and projects on adaptation to climate change (NAPA – Bangladesh, Bhutan, Burundi, Cambodia, Cape Verde, Comoros, Eritrea, Ethiopia, Lesotho, Mauritania, Niger, Rwanda, Samoa, S. Tome & Principe, Sudan, Zambia, Tanzania, Tuvalu, Uganda; NC – India, Brazil, Nepal). This limitation can extend to the community level due to forest dependence and subsistence conditions (NAPA – Malawi; NC - India).

It is noted that delaying the initiation of adaptation actions may increase the vulnerability of systems and/or increase the costs of adapting (NAPA – Bangladesh). This may have significant ramifications for developing nations which are already facing financial limitations for adaptation.

A summary table of projects proposed for implementation in the NAPAs is provided in Annex 3 – NAPA Projects related to Forests

Box 1 - Extract from the Indian NC, outlining policy, programmes and practices which are increasing the vulnerability of forests to climate change. (NC – India; 102)

- "Forest fragmentation leading to loss of biodiversity by hampering migration of species.
- Forest degradation leading to loss of biodiversity, affecting forest regeneration.
- Dominance of monoculture species under afforestation increase vulnerability to fire, pests, etc.
- Absence of fire protection and management practices enhance vulnerability to fire.
- Non-sustainable extraction of timber, fuelwood and NTFPs leading to degradation of forests, fragmentation of forests and affecting shift of forest boundaries and regeneration of plant species.
- Inadequate fuelwood conservation programmes increases pressure on forests, leading to degradation.
- Inadequate and less-effective implementation of the different conservation programmes leading to forest degradation."

Extract from the Indian NC, outlining policy, programmes and practices which are decreasing the vulnerability of forests to climate change. (NC – India; 102)

- "The forest Conservation Act 1980, Wild Life Act, Protected Areas and other policies contribute to forest and biodiversity conservation and reduction of forest fragmentation.
- A large afforestation programme has reduced the pressure on forests for timber, industrial wood and fuelwood, leading to conservation of biodiversity and reduction of forest degradation.
- Involvement of local communities in forest protection and regeneration and creation of long-term stake in forest health, through the Joint Forest Management (JFM) programme."

3.1.4.1 Regulatory Instruments

The national reports indicate that regulatory instruments can be used for reducing the *general vulnerability* of forests to climate change. Forest conservation, in the form of formal protection areas and SFM are highlighted as an adaptation option for climate change (NAPA – Burundi, Djibouti, D.R. Congo, Guinea, Guinea-Bissau, Senegal, Samoa, Tanzania; NC – Brazil, Cameroon, Sierra Leone, United Arab Emirates, India, Nepal, Rwanda). This is due to a reduction of external stresses (e.g.

fragmentation) on the forest systems and formation of a more stable forest system (NC – India).

Forest protection areas, such as national parks, are particularly required in regions of important or vulnerable forest types as a method of adaptation to climate change (NAPA – Guinea-Bissau, Samoa, Tanzania; NC – Brazil, India, Nepal, Rwanda, Mexico). Linking protected areas, wildlife reserves and forest reserves is reported as a method of reducing the vulnerability (NC – India).

Notably, due to the current climatic conditions the protection of degraded areas for the purpose of rehabilitation may not result in environmental improvement (NC - Saudi Arabia). The NC for Saudi Arabia, for example, reports that in areas which have been protected from grazing the trees remain stunted as a result of low rainfall and high temperatures.

Throughout the tropical domain there are problems with the implementation of regulatory policy, such as for protective areas, as there is a general lack of resources for the enforcement of such measures (NAPA – Cape Verde; NC – Brazil, Nepal). As a result protected areas continue to be degraded through illegal practices (NAPA – Cape Verde; NC – Brazil, Nepal), and exceeding of cutting concessions (NC – Nepal). Efforts to combat deforestation are also reported to be limited by a lack of adequate policy coupled with insufficient means for enforcement (NC – Brazil, Sierra Leone). Brazil, however, presents a number of policies aimed at reducing deforestation and to protect conservation areas (NC – Brazil).

Regulatory and informative instruments outlined in National Forest Programmes, Forest Law or equivalents are utilised for the promotion of SFM, afforestation and reforestation (NAPA – Bangladesh, Rwanda, Guinea, Guinea-Bissau, S. Tome & Principe, Vanuatu, Zambia; NC – Brazil, India, Fiji, Mozambique, Nepal, Rwanda, Sierra Leone, Guinea-Bissau). Some environmental projects such as the Guinea-Bissau Biodiversity and Coast Management Project also aim at creating regulatory tools for environmental protection and the incorporation of environmental costs into policy development, although specific instruments are not included (NAPA – Guinea-Bissau). Projects outlined in the NAPAs which are concerned with forests and natural

environment are often initiated through the national Ministerial department for environment or forestry (NAPA – Bhutan, Burundi, Cambodia, Comoros, Ethiopia, Lesotho, Malawi, Niger, S. Tome & Principe, Zambia, Uganda, Vanuatu). There is also reference to NGOs when detailing how projects will be implemented, although specifics are not commonly mentioned (NAPA – Bangladesh, Cambodia, Comoros, Guinea-Bissau, S. Tome & Principe, Tanzania; NC - Nepal.). Although costs for running projects are identified, the source of the funding is not explicitly mentioned in most NAPAs (NAPA - Bangladesh, Bhutan, Burundi, Cambodia, Cape Verde, Comoros, Eritrea, Ethiopia, Lesotho, Mauritania, Niger, Rwanda, Samoa, S. Tome & Principe, Sudan, Zambia, Tanzania, Tuvalu, Uganda)

Institutional strengthening of departments and bodies concerned with forest management, research and protection, including their ability to enforce legislation, is identified as a necessary step in decreasing the vulnerability of forests to climate change (NAPA – Mauritania, S. Tome & Principe; NC - India). This is reported to be achieved through increasing the human and technological resources (NAPA – Mauritania). Similarly, there is a need to improve the effectiveness of existing policy and guidelines pertaining to forest management and protection, incorporating climate change (NC – India, Tonga). The NC of Nepal stipulates that forest policy needs to amplify the responsibility of those involved with forests as well as provide information on adaptation options.

Similar strengthening of community based and participatory forest management is viewed as a method of adapting to climate change (NAPA – Benin, Burkina Faso, Cambodia, Djibouti, Guinea, Tanzania, Ethiopia, Zambia; NC – Fiji, Nepal, Rwanda, Sierra Leone).

Examples of some regulatory measures are:

- National legislation (National Code of Logging Practice) coupled with a “green certificate” from the Forest Stewardship Council (FSC) is being used to promote SFM, (NC – Fiji).

- Proposed policy where by there would a minimum percentage of irrigated agricultural land required to be forested. This is expected to increase the resilience of the communities (NAPA – Sudan).
- Regulatory audits of sawmills as a method of avoiding deforestation is being implemented in Brazil (NC – Brazil).
- *The Green Protocol* – In an attempt to combat deforestation, the Brazilian public banks have signed a declaration that all publicly funded projects must be environmentally sustainable and comply with environmental law (NC – Brazil).
- *Rural and Agriculture Policy* of Ethiopia promotes reforestation and conservation, and community based participatory projects (NAPA – Ethiopia).

As previously identified, different *topography* is associated with different impacts with regards to forests, accordingly topographic specific adaptation options are identifiable within the national reports.

Nepal reports legislation against deforestation in mountainous regions in an attempt to reduce the probability of landslides and erosion, however there is no mention of policy instruments, or of the effectiveness of the measures taken (NC – Nepal).

Associated with the projects concerned with extreme events, national policy has been developed which outlines actions of mitigation, response and recovery from extreme weather events, however this is not specific to forests (NAPA – Kiribati).

3.1.4.2 Economic Instruments

Within the national reports of countries with a developing economy there is a notable trend of utilising community based projects to mitigate and adapt to the *general impacts* of climate change (NAPA – Bangladesh, Benin, Bhutan, Burkina Faso, Cambodia, Comoros, Djibouti, Guinea-Bissau, Ethiopia, Malawi, Senegal, Uganda; NC – Fiji, Nepal). In Nepal, community based forest management has been enacted through the national Forest Act and provides communities with the right to form forest users' groups and to manage forests under the Principe of SFM (NC – Nepal). This is common for projects which promote afforestation and forest protection for the preservation of ecosystem benefits (E.g. NAPA – Burundi, Comoros, Eritrea,

Ethiopia, Guinea-Bissau, Haiti, Rwanda, Samoa, S. Tome & Principe, Senegal, Sudan; NC – Nepal, United Arab Emirates, Madagascar, Mexico). One strategy to combat the degradation of protected areas is the initiation of income generating projects in communities located near the boundaries of protected areas (NC – Rwanda).

Afforestation, with both endemic and exotic species, is viewed as a method of preventing/rehabilitating climate change induced desertification and land degradation, erosion and disruptions to water quality (NAPA – Bangladesh, Bhutan, Comoros, Eritrea, Guinea-Bissau, Malawi, Niger, Rwanda, Senegal; NC – Cameroon, Rwanda). Afforestation projects are also anticipated to alleviate the stress on primary forests exerted by subsistence communities by increasing the available forest for fuel wood (NAPA – Malawi; NC – India, Sierra Leone, Brazil, Cameroon). Additional to community based projects, national afforestation projects have been initiated throughout the topical domain (NAPA – Tanzania, Rwanda; NC – Argentina, Mexico). Uganda reports that the projects outlined in their NAPA will need to be funded via the "Government of Uganda, Bi-laterals, Multilaterals, NGOs and CBOs [Community Based Organisation]" (NAPA – Uganda, p. 53). Other NAPAs report the implementing department/organisation, although not whether these will be the source of funding.

Despite afforestation efforts it is also reported that the amount is insufficient to compensate for the level of deforestation (NC – Nepal).

Financial incentives, in the form of micro-credit, are used to finance management measures which promote sustainable resource management and agroforestry (NAPA – Cape Verde). Formation of an incentives scheme for the reforestation of degraded land is highlighted as an adaptation option (NAPA – Ethiopia) as is providing financial and technical support for technical services in forestry (NAPA – Guinea-Bissau). However it is reported that due to financial limitations, the utilisation of financial mechanisms may be restricted (NAPA – Cape Verde).

The United Arab Emirates NC reports the use of subsidies for home and land owners who plant trees. Although this was done to improve the "greenness" of the country

and to increase self sufficiency (with planting of fruit trees), it also serves as a mitigation and adaptation response to climate change (NC – United Arab Emirates). In Brazil, financial incentives have been established for the protection of private forests, namely tax incentives (no property tax paid) coupled with government protection of these forests from fire, hunting and deforestation (NC – Brazil). These areas are known as the Private Heritage Natural Reserves (RPPNs) (NC – Brazil).

Brazil suggests that a "protector receives" system as opposed to "polluter pays" is a better mechanism for environmental protection in poverty stricken regions. This is because poorer communities are motivated more by financial incentives rather than disincentives (NC – Brazil). This could be distributed through "Ecological ICMS" (Ecological Tax on the Circulation of Goods and Services) (NC – Brazil).

Financial investment in infrastructure which will aid in adaptation is reported (NAPA – Tanzania). For example, the use of investment to increase the utilisation of alternative energy sources such as gas or hydroelectricity (NAPA – Tanzania, Mauritania).

3.1.4.3 Informational Instruments

Capacity building through the dissemination of information (i.e. training, research etc.) is frequently mentioned throughout NAPAs and NCs (NAPA - Bangladesh, Ethiopia, Mauritania, Vanuatu; NC - Sierra Leone, Tonga), as is the identification and monitoring of vulnerabilities and possible future impacts of climate change as a necessary activity for adaptation (NAPA – Samoa, Mexico). Throughout the tropical domain there are numerous projects which aim at informing communities and landholders about the predicted impacts and adaptation options available for coping with climate change; included in this is the dissemination of information pertaining to SFM (NAPA – Cape Verde, Bangladesh, Mauritania, Tonga; NC - India). There are mechanisms in place for environmental risk assessment, so that potential risks can be addressed (NAPA – Kiribati). Similarly, the monitoring of the impacts of drought through multilateral collaboration is promoted as a means of adapting to climate change (NAPA – Mauritania).

Information on the current situation of forests is required in order to estimate baseline figures, identify vulnerable forest types and develop appropriate adaptation options (NC – Solomon Islands). This may pose a problem for countries with limited resources where it has been more than two decades since the last forest assessment (NAPA – Mauritania, Guinea-Bissau; NC – Solomon Islands). Similarly, it is reported that there were limitations on reporting on the impacts of climate change due to gaps in forest data, reiterating the need for further research (NC – Nepal, United Arab Emirates).

The models used to predict the impacts of climate change on forests need to be improved to reduce the level of uncertainty and increase the capacity for adaptation (NC – Nepal, Brazil). This is of particular importance for countries with a developing economy where multiple attempts at adaptation may not be financially feasible.

There is a need for the incorporation of climate change into short and long term planning at all levels of decision making, from forest working plans to the long-term policy making process (NAPA – Uganda; NC – India, Brazil). Additionally, sustainable development needs to occur where by the socio-economic development of a country is balanced with the environment (NAPA – Bhutan, Zambia; NC – Fiji, Brazil). Information pertaining to environmental stresses has been incorporated into the national policy of some countries, such as Zambia, with the National Policy on Environment, Forest Act and Forestry Policy (NAPA – Zambia).

Some NAPAS refer to the dissemination of information pertaining to adaptation options available for forest managers for adapting to *physiological changes* (NAPA – Cape Verde; NC – Brazil, United Arab Emirates). One adaptation option promoted by informational instruments is to change the species composition; in particular the expansion of endemic and exotic drought resilient tree species, as well as the introduction of fast growing exotic species is to increase the resilience of forests to the future climate (NAPA – Eritrea, Guinea-Bissau, Rwanda, Samoa, Tanzania; NC – Rwanda, Sierra Leone). This includes the establishment of community woodlots (NAPA – Zambia, Tanzania, Senegal; NC - Sierra Leone).

As with many projects mentioned in NAPAs and Non-Annex I NCs, it is suggested that these aims be carried out through community based forest projects (NAPA – Eritrea, Bhutan, Burundi, Guinea-Bissau).

To cope with changes in the ability of some species to regenerate, it is suggested that the rate of harvest and deforestation be reduced to compensate (NAPA – Zambia). Additionally, Zambia promotes the retention of traditional species in order to meet the requirements of society in regards to timber and non-timber products (NAPA – Zambia).

Comments on the impacts of forest genetics was limited for the tropical domain, as were adaptation options and policies. However, some countries mentioned national policy and projects advocating the protection of genetic diversity (NAPA – Tanzania, NC – Rwanda, Cameroon). Utilisation of natural regeneration was promoted, although not for the maintenance of genetic diversity (NAPA - Eritrea, Mauritania, Tanzania; NC – India, Nepal).

NAPA projects also focus on capacity building and the dissemination of information to increase the public awareness of the potential problems and solutions (NAPA – Bangladesh, Mauritania, Vanuatu).

The utilisation of forests as a means of protecting communities and the ecosystem benefits, in particular the protection of watersheds, is documented in several NAPAs and NCs (NAPA – Bangladesh, Bhutan, Cambodia, Eritrea, Rwanda, Samoa, Zambia; NC - Fiji). This can be achieved through the afforestation of coastal and mountainous areas (NAPA – Bhutan, Cambodia, Eritrea, Rwanda).

The implementation of such afforestation projects is commonly linked with the national forest or environmental departments, as well as Non-Governmental Organisations (NGOs) (NAPA - Bhutan, Cambodia).

The use of experts for community based training on methods of afforestation and tree growing is suggested, although it is noted that funding of such a project poses a problem for countries with a developing economy (NAPA – Bangladesh). Methods

such as this are also expected to improve the socio-economic situation of communities through the creation of employment opportunities (NAPA – Bangladesh).

To cope with the loss of fuel-wood and to reduce the anthropogenic impacts on primary forests, some nations aim to use policy to promote the use of non-timber fuel for heating and cooking, including solar, wind, and gas (NAPA – Mauritania, Eritrea, Rwanda, S. Tome & Principe, Sudan, Tanzania; NC – Nepal, Rwanda, Solomon Islands, Suriname). An example can be seen in Mauritania, where moves away from fuel-wood are intended to be promoted through the national strategy for adapting to climate change. This is to be achieved by informing communities on the need to move away from wood based fuels, coupled with measures to provide affordable butane gas to households and employment for those displaced from the wood selling business (NAPA – Mauritania).

Agroforestry is promoted as a means of mitigating the potential impacts of climate change on the environmental and social sector, in particular for increasing fuel wood supply and improving agricultural enterprises (NAPA – Eritrea, Ethiopia, Burundi, Cambodia, Cape Verde, Comoros, Ethiopia, Mauritania, Samoa, Sudan, Vanuatu; NC – Nepal, Rwanda, Sierra Leone, Tonga, Mexico). It is also seen as a means of stabilising vulnerable areas, such as sand dunes (NC – Turkmenistan).

Improvement in the efficiency of stoves and heating devices is also outlined as a measure for reducing people's impacts on forests (NAPA – Eritrea, Guinea-Bissau, Zambia; NC – Nepal, Rwanda).

3.1.4.4 Summary of Policies for Adaptation and Instruments

The countries that are located in the tropical domain have a limited ability to adapt to climate change due to the high dependence on forests and limited financial resources. Generally, the adaptation options for the tropical domain focus on reducing the anthropogenic stresses on forests through the use of regulatory, economic and informational instruments.

Regulatory instruments focus on reducing the external stresses on forests through forest conservation, such as formal protected areas, and SFM. These are implemented by national laws, and programmes, such as the national forest programme.

However, it is noted that there are problems in enforcing such initiatives due to limited financial and human resources and a lack of adequate policy. It is reported that there is a need for institutional strengthening of departments and bodies concerned with forest management, research and protection, if these measures are to be successful.

Economic instruments will be required for the successful implementation of the community based and national programmes reported in the analysed reports. The programmes have a strong focus on afforestation as a means of stabilising the environment and as an alternative source of timber for communities, thus reducing pressure on primary forests.

Economic incentives for SFM, reforestation and changes to non-wood based fuels are also mentioned as a necessary step towards adaptation. It is also reported that communities in high poverty areas are more inclined to implement changes if there are financial incentives, rather than disincentives. However, again, it is noted that a lack of financial resources may impede the utilisation of economic instruments.

Capacity building through the dissemination of *information* pertaining to vulnerabilities and adaptation options is a valuable instrument for adaptation to climate change. This can be achieved through national projects promoting education, training and SFM, and the incorporation of climate change into the necessary short and long term planning processes.

It is also reported that the establishment of monitoring programmes to determine the current situation of forests and implementation of further research into future predictions of climate change, including extreme events, is an important measure for adaptation.

3.1.5 Mitigation Measures

Mitigation through afforestation, reforestation, argoforestry and sustainable land management is recognised within some NCs (NC – Nepal, Tonga, Suriname, United Arab Emirates, Madagascar, Venezuela, S. Tome & Principe). Throughout the tropical domain there are numerous reports of programmes and projects aimed at afforestation (NAPA – Burundi, Comoros, Eritrea, Guinea-Bissau, Rwanda, Samoa, S. Tome & Principe, Sudan; NC – India, Nepal, Rwanda, Tonga). Although the mitigation of climate change through carbon sequestration tends not to be the primary objective of these projects, which are aimed more at environmental stability, they will result in an increase in carbon sequestration and carbon sinks (NAPA – S. Tome & Principe).

Forest protection for the purpose of mitigation is also raised in some reports (NC – Guinea-Bissau, Fiji, Venezuela). Although Fiji reports that there is a desire to increase protected areas for the use as a carbon sink, it states that this goal is restricted by a lack of financial resources (NC – Fiji). However, if additional funding was available, compensatory payments would be made to forestry companies for loss of revenue (NC – Fiji). Increased harvesting efficiency is also reported as a means of mitigating climate change (NC – Suriname).

Some countries have developed a National Action Plan on climate change, incorporating mitigation through maintaining and strengthening carbon sequestration (NC- Madagascar, United Arab Emirates). Also mentioned are institutional strengthening and the dissemination of information, although this is not specific to forests (NC- Madagascar, United Arab Emirates).

There is a need to further develop monitoring and regulating systems on carbon sequestration levels (NC – Nepal). It is recommended that a process be developed for payments for carbon credits for forested land, sustainably managed forests and agroforestry projects (NC – Nepal, Gabon).

3.2 Sub-Tropical Domain

The sub-tropical domain is characterised by at least 8 months with a mean temperature above 10^{o}C. It is located between 25 and 40 degrees in latitude, in both hemispheres. It is located poleward of the tropical domain, and equatorial of the temperate domain. The lowland zones are from sea level up to approximately 1000 meters. The sub-tropical domain is delineated into five GEZ, those being:

- Subtropical humid forest
- Subtropical dry forest
- Subtropical steppe
- Subtropical desert
- Subtropical mountain systems

The vegetation which characterises this domain is typical of the Mediterranean, humid, arid and semi-arid zones, with a mixture of coniferous, deciduous and evergreen sclerophyllous species. The sub-tropical GEZs cover approximately 22.7 million km^2. 21 national reports from the sub-tropical domain were analysed. Annex I Countries which are contained within this region and have produced a NC are Australia, United States of America, Croatia, France, Greece, Italy, Japan, Monaco, New Zealand, Portugal, and Turkey. Non-Annex I countries include Argentina, Bahrain, Brazil, China, Mexico, Saudi Arabia, Turkmenistan, and Uruguay, and countries who developed a NAPA include Lesotho and Maldives.

3.2.1 Observed Impacts

There has been an observed lengthening of the growing season related to the warming of the climate (NC - Italy). There has also been an increase in climate variability resulting in an increase in dry periods and heavy rain events observed in southern and central Italy (NC – Italy).

Within the Mediterranean regions of the sub-tropical domain there has been an observed increase in the number of heat waves that occur (NC – Greece, Portugal). This has resulted in a decline in forest health, as well as having social impacts.

The occurrence of pest and disease outbreaks has been observed to have increased as a result of climate change, in particular during extended dry period which weakens the tress making them more susceptible to insects and diseases (NC – Croatia). In addition there has been a poleward spread of pests and diseases, into areas where previously they were not found (NC - Japan).

Sub-tropical vegetation, Botswana

3.2.2 Vulnerabilities and Future Impacts

The NCs provide an overview of the current situation in the sub-tropical domain, with an overall theme that the domain is particularly vulnerable to the detrimental impacts of climate change (NC – Spain, New Zealand, Australia, China, Uruguay, Croatia, Italy; NAPA - Lesotho). The vulnerability of these forests is determined by their natural resilience and the existing anthropogenic pressures (NC - China). Forests occurring in areas which are at the limits of growing conditions are highly vulnerable to climate change; with even modest changes in climate having potentially severe consequences (NC – Spain, New Zealand, Australia, & Italy).

Forests which are currently in a stressed state due to poor management such as over harvesting are predicted to degenerate further under changed climatic conditions (NAPA – Lesotho).

It is predicted that there will be an increase in temperature and a decrease in precipitation throughout the sub-tropical domain (NC – Japan, New Zealand; NAPA – Lesotho, China).

3.2.2.1 Topographic Delineation

Coastal Areas

Coastal areas are vulnerable to climate change (NC – Australia, Spain, China, Bahrain). China and Bahrain report that mangrove forests are particularly vulnerable to climate change (NC – China, Bahrain). Bahrain reports that it is likely for there to be inundation of coastal mangrove forests as a result of sea level rise, while China predicts a north-ward extension of the growing area of mangroves due to an increase in average surface temperature (NC – Bahrain, China). Although the Japanese mangroves are likely to be inundated by raising ocean levels to some extent, it is not expected to be dire for this forest type, as the average ocean height (average of high and low tide) is predicted to be below the current mangrove level.

Anthropogenic activities such as deforestation and commercial development increase the vulnerability of mangrove forests and limit the capacity for inland migration under higher sea levels (NC – Bahrain).

Lowlands

Some forest types will be more vulnerable to climate change than others. Low land forests in New Zealand, for example, are vulnerable to detrimental impacts as a result of these forests having a limited climate niche, which is likely to be further reduced under predicted climate change.

Mountains

Mountainous forests and alpine ecosystems are highly vulnerable to climate change (NC – Australia, Japan, Italy, Spain). It is predicted that there will be an upward migration of mountainous species as a result of climate change (NC – Italy, Portugal), while changes in the over wintering snow condition will likely impact Japanese mountainous forests, resulting in earlier blooming and an increase in damage due to the loss of snow protection (NC – Japan).

3.2.2.2 Physiological Changes

Changes in climate are also likely to impact species distribution and species composition within the sub-tropical domain (NC – Argentina, Spain, Japan, New Zealand, Italy, Portugal, United States of America, China, Croatia). For example, the Japanese NC states that it is expected that the sub-tropic forests of Japan will need to migrate north by approximately 500km and/or in altitude by 500m over the next 100 years in order to adapt to the changing climate. This poleward (north in the Northern Hemisphere, south in the Southern Hemisphere) and upward shift is predicted to occur across the domain, with differing severity and consequences (NC – New Zealand, Italy, Portugal, Spain, United States of America, China). Notably, a forest species ability to migrate over substantial distances, such as those predicted, is likely to be restricted by geographic and anthropogenic factors such as mountains, oceans, cities, roads, and agriculture (NC –Japan).

The changing climate will allow some species to expand their geographic range, such as cork oak and pine in Portugal, which is predicted to migrate upwards as a result of

climate change (NC – Portugal). Other species' geographical range is likely to be restricted by other environmental conditions, such as inadequate water, resulting in a reduced area, such as deciduous pine in China (NC - China).

Overall, it is anticipated that the area of the sub-tropical forests will expand into the temperate domain, and existing sub-tropical forests will restrict in area and reduce in productivity (NC – Italy, Croatia, Spain, France and Portugal). This is predicted to include the migration of forest species from the inland coast-ward (NC – Portugal).

It is unclear if the impacts of this will reduce species richness at the domain level or if it will be confined to the local level.

Growth rates are expected to increase as a result of an extended growing period (NC – Spain, Italy, Greece, Uruguay). However, it is noted that an increase in growth rates alters the natural balance of an ecosystem, increasing the vulnerability to climate change (NC – Spain). Additionally, an increase in temperature and subsequent decrease in available water is likely to negatively impact on vascular plants (NC – Spain, Uruguay).

3.2.2.3 Extreme Events and Disturbances

Throughout the sub-tropical domain it is anticipated that there will be an increase in extreme weather events and weather variability (NC – Argentina, Australia, Croatia, Italy, France, Spain Japan; NAPA - Lesotho). This includes an increase in drought, fire, and strong winds (NC – Croatia, Australia, Portugal, Italy, Spain, Argentina; NAPA – Lesotho)

The occurrence of fire, pests and pathogens is predicted to increase in forested areas as a direct or indirect result of climate change (NC – Argentina, Spain, Australia, Croatia, Italy, Portugal, Turkey). For example, some insect species are predicted to be able to complete two biological cycles within one year as a result of milder winters (NC – Spain).

It is predicted that the observed increase in the number of heat waves occurring in the Mediterranean region during the summer months will continue (NC – Italy, Portugal). In addition, it is anticipated that there will be a general decrease in precipitation across the region, increasing the vulnerability to fire (NC – Italy, Turkey, France, Uruguay & Australia; NAPA - Lesotho). An increase in fire and drought, coupled with anthropogenic activities is likely to increase the vulnerability of desertification (NC – Argentina, Greece, Spain, Italy).

3.2.2.4 Social Impacts

The social benefits of forests may be jeopardised through a loss of ecosystem services, such as soil protection and hydrological cycling (NC – United States of America, Portugal; NAPA - Lesotho). In countries with a developing economy where communities rely directly on forests for fuel wood for heating and energy, climate change may destabilise the supply of timber (NC – Lesotho). Furthermore, the viability and competitiveness of the forest sector may be impacted due to a loss of tree productivity, and consequently, there is a risk of unemployment for those involved in the forest sector (NC - Portugal).

The predicted changes in forest ecosystems also have social implications, and inversely the changes observed are often driven by anthropogenic actions, as exemplified by Turkey. Within the Turkish 4th NC it is reported that 85% of the country is highly vulnerable to desertification due to the country's socio-economic status as well as its cultural and economic heritage. Furthermore a predominant cause of fire is through anthropogenic ignitions (arson, carelessness etc.) (NC – Italy). Fire, as previously mentioned, contributes to the desertification process, which in turn has social implications. In regions where there is vulnerability to fire and desertification it is likely to detrimentally impact on human health and wellbeing through the loss of ecosystem services. For example, a loss of arable land leads to economic stress (NC – Turkey & Italy).

3.2.2.5 Summary of Vulnerabilities and Future Impacts

It is predicted that there will be an increase in temperature and a decrease in precipitation across the domain as a result of climate change. Some regions of the sub-tropical domain are vulnerable to modest changes in climate as a result of being located at the limits of growing conditions.

As a result of these changes it is expected that there will be an increase in extreme events and disturbances, such as drought, fire, and the expansion of the geographic range of insects and diseases, predisposing forests to degradation and desertification in some regions. It is also predicted that there will be an increase in growth rates associated with extended growing periods, although this may increase the instability of forest ecosystems, and consequently increase the vulnerability of these ecosystems to climate change.

In some regions mangrove forests are vulnerable to inundation from sea level rise, as well as from storms and deforestation. In other regions lowland and mountainous forests are also vulnerable to climate change due to limited ecological niches and ability for migration.

It is predicted that climate change will result in an poleward shift in species composition of up to 500km and in altitude up to 500m over the coming century. The ability of species to achieve such a shift is predicted to me hampered by fragmentation and physical boundaries, such as mountains, cities, roads and agriculture.

Desertification may impact on the socio-economics of countries, including a loss of cultural heritage.

3.2.3 Management for Adaptation

Forest management can be carried out in such a manner that resilience and adaptive capacity of forests to climate change is enhanced. Although not specifically related to the sub-tropical region, the NC from France identifies the following adaptation measures recommended for forestry:

- Genetic selection or selection of trees from specific varieties/origins
- Promote mix species forests
- Decrease the area of monocultures
- Improve the monitoring of pests and diseases

Similarly, alterations in forest management and management plans should aim at maintain high genetic diversity though careful seed collection and alterations in harvesting (NC – Spain, Uruguay). Through reforestation with high-quality mangrove seeds it is possible to aid the northward migration of forest species, such as mangroves in China (NC – China). Reforestation is also reported as a method of adapting to increased temperatures, and the occurrence of drought, fire, diseases and wind storms (NAPA – Lesotho). Reducing stresses from extreme weather events, such as fire, disease and pests, as well as anthropogenic pressure, and the connecting of nature reserves with corridors is reported as a method of adapting to climate change (NC – China).

Similarly, forest management that improves forest health, prevents fires and promotes reforestation is outlined as an option for combating desertification (NC – Greece).
As a result of the impacts on forests from climate change it is likely that there will need to be changes in the harvesting patterns in order to optimise the forest resource (NC – Spain, China). The NC from China promotes the use of artificial forests as a source of timber, rather than relying on natural forests.

3.2.4 Policies for Adaptation and Instruments

3.2.4.1 Regulatory Instruments

The formation of a National Plan for Adaptation to Climate Change is an important step in the adaptive process (NC – Spain, Argentina), although forests are not explicitly mentioned as an aspect of these plans.

In New Zealand responsibility is placed on the local authorities to adapt to and mitigate the impacts of climate change. This includes clear legislation which outlines who is responsible for ensuring adaptation is incorporated into long term planning. The Australian NC also identifies the need for climate change to be included in long-term planning.

Importantly, with the introduction of new regulatory measures it is necessary to provide detailed information on how to meet the provisions of the new legislation (NC – New Zealand).

Regulatory requirements on forest management are used to promote SFM and forest protection, such as the Forest Act and environmental law (NC – Argentina, Croatia, Japan, Australia, Portugal, Italy, and United States of America).

Through National Action Plans against fire and desertification, policy is reported to be addressing the risk of *extreme events* (NC – Spain)

The Greek NC reports that measures will be taken in forestry to reduce the impact and vulnerability to desertification though afforestation, fire prevention, and improvements in forest health. These are implemented through the Operational Programme for Forestry.

Similar to the laws and regulations introduced in New Zealand, France has implemented law which requires that natural risks be incorporated into regional planning (NC – France). There has also been an improvement in the alert system for natural risks (NC – France).

3.2.4.2 Economic Instruments

Programmes which offer financial support for improving the environmental conditions are reported (NC – Australia, Argentina). These include tax incentives (deductions) and subsidies for the expansion of plantations (NC – Australia, Argentina) and grants for environmental plantings (NC – Australia). Although these measures are not specifically aimed at increasing the adaptive capacity of forests, they can be viewed as achieving this. Similarly, New Zealand has a local afforestation programme which utilises financial instruments for its implementation (NC – New Zealand). Subsidies are provided for SFM of public forests (NC – Spain).

3.2.4.3 Informational Instruments

The dissemination of information is an important instrument for adaptation to climate change. The National Forestry Act, National Adaptation Strategy or an equivalent process is utilised when discussing adaptation of forests and the forest sector to climate change (e.g. NC - Croatia, Australia). These Acts and Strategies are stated to include information on the predicted impacts, vulnerabilities and adaptation options for climate change (NC – Australia, Greece).

New Zealand has introduced a separate framework for evaluation of the possible impacts of climate change, where at first qualitative information is collected on a possible risk, followed by a quantitative assessment and recommendations (NC – New Zealand).

There is a need to develop forest models which account for the predicted changes in the climate so that management can be adjusted (NC – Spain). Similarly it is reported that the continued monitoring of the impacts of climate change on major ecosystems is a necessary step for adaptation (NC – Uruguay, Spain).

It is possible that national reports identify adaptation options which have been planned or implemented which are not mentioned within the NCs.

Policy measures which promote the distribution of information on the impacts and vulnerabilities of climate change, in particular *extreme events*, are gaining importance as impacts are starting to be realised. In southern Italy for example forests ecosystems

are predicted to become more susceptible to fire events. To combat this, the Italian NC reports that through the introduction of a fire education programme it was possible to reduce the number of anthropogenic fires.

The dissemination of information on climate change has also been used to increase the adaptive capacity of society. In Portugal (NC) for example there have been leaflets distributed to the general public on methods to reduce the impact of drought, fire and heat waves; however this is not specific to forests and the forest sector. Additionally the Australian NC identifies the need to provide information on the likely impacts of climate change, adaptation options and guidelines as well as tools for risk management.

3.2.4.4 Summary of Policies for Adaptation and Instruments

Regulatory instruments have been implemented which define who is responsible for the incorporation of adaptation into planning. As with the tropical domain, forest policies such as Forest Acts or equivalent are used to promote SFM. Measures have also been taken to reduce the vulnerability to desertification though afforestation, fire prevention and improvements in forest health.

Economic instruments in the form of tax incentives and subsidies are used for promoting plantation expansion and environmental plantings. They are also used to promote the sustainable forest management of public forests.

Informational instruments are incorporated in national Forest Acts, National Adaptation Strategies or equivalents, and disseminate information on adaptation options to climate change. It is reported that forest models need to incorporate climate change so that management can be adjusted accordingly. Some regions have implemented education programmes to increase the capacity to cope with extreme events, and to reduce the occurrence of anthropogenic induced fire.

3.2.5 Mitigation Measures

Mitigation measures which were reported by the NCs were generally associated with the promotion of SFM and afforestation/plantation expansion for the purpose of increasing the potential carbon sequestration levels (NC – Argentina, Australia, Portugal, France, New Zealand, Spain, Uruguay, & United States of America). This was done through the dissemination of information and advice (NC – United States of America, Australia) as well as through economic incentives (NC – Australia, Portugal, New Zealand, China & United States of America). The use of fiscal incentives was favoured for promoting plantation establishment. China reports afforestation of agricultural land as a means of mitigation through the national "Grain for Green" project (NC – China). This project provides funds for seedlings and compensates land holders for lost cropping area with 2.25 tonnes of grain per year for every afforested hectare of arable land (150kg/mou[6]) (NC – China). If this volume of grain is less than was produced, the agriculture tax for the land is reduced (NC – China). This project was first mentioned in 1998 as a priority Post-Disaster Reconstruction measure (NC – China).

Included in the concept of SFM is forest protection and rehabilitation, which is reported to have been promoted through voluntary and regulatory means (NC – Australia, France).

The French NC reports that through regulatory measures a minimum quota will be set for the inclusion of timber utilised in new constructions. France also aims to develop the wood-energy sector through improved harvesting methods and increased harvesting (NC – France). Land holders will also be informed on the best means to reduce their GHG emissions and improve the carbon sequestration and source inventories (NC – France).

[6] 1 mou equates to 1/15 of a hectare

3.3 Temperate Domain

The temperate domain is located poleward of the sub-tropical domain, and south-ward of the boreal domain (there are no boreal forests in the Southern Hemisphere), and predominantly occurs in the Northern Hemisphere. It is characterised by 4 to 8 months of average temperatures above 10^{o}C. The temperate domain encompasses five GEZ, namely:

1. Temperate oceanic forest,
2. Temperate continental forest,
3. Temperate mountain systems,
4. Temperate steppe and
5. Temperate desert.

This classification includes large amounts of forestland found in Central Europe, Central Asia, and North America. This domain is characterised by broad-leaved deciduous, mixed broad-leaved deciduous and coniferous, and pure coniferous forest types in the Northern Hemisphere, while in the Southern Hemisphere by coniferous, dry evergreen forests, evergreen rainforests, and broad-leaved evergreen forests. The temperate GEZs cover approximately 27.3 million km^2.

37 national reports are included in the temperate domain. Countries located within this domain which have submitted a NC are Australia, Austria, Belarus, Belgium, Bulgaria, Croatia, Czech, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Netherlands, New Zealand, Poland, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, and the United States of America. Non-Annex I countries are China and Turkmenistan.

3.3.1 Observed Impacts

There has been an observed increase in temperature, including warmer winters, and changes in the hydrological regime (NC – Austria, Switzerland, Latvia, Lithuania, Ukraine). Similarly, observed changes in forest ecosystems are reported, which have been at least partly attributed to climate change (NC – Austria, Belarus, Belgium, Bulgaria, Croatia, Czech, Germany, Latvia, Lithuania, Russia, Sweden, Switzerland, Ukraine). These changes include a decline in forest health (NC – Bulgaria, Belgium, Germany, Italy), an increase in extreme events and disturbances (NC – Austria, Belarus, Belgium, Croatia, Latvia, Russia), as well as changes in species distribution and composition (NC – Belgium, Lithuania, Ukraine) and species phenology (NC – Lithuania, Sweden).

In some regions there has been a noted trend of increasingly variability in climatic conditions, with increases in dry periods and the occurrence of heavy precipitation events (NC – Italy, Germany, Switzerland, Poland, Ukraine, Russia).

Visible impacts on forests associated with this climate variability are occurring due to the lengthening of the growing season and a decrease in available water (NC – Austria, Italy). Consequently there has been a decline in forest health, as observed in Italy where there has been deterioration in oak forests as a result of water stress (NC – Italy). This trend has been reported within multiple NCs with observations of decay in forest conditions observed across continental Europe (NC - Belgium, Germany, Bulgaria).

In areas where there has been a warming of the climate, but species are not experiencing a water deficit, there has been an observed expansion of forests (NC – Italy, Austria).

There has also been an increase in extreme events and major disturbances, such as damaging storms, fire, and insect attack, all of which have been associated with climate change (NC – Austria, Belarus, Belgium, Croatia, Latvia, Russia).

As a result of climate change and the increase in extreme events, there has been a change in forest composition (NC – Latvia). In Latvia, for example, there has been an increase in the area of deciduous forests, increasing by 12% over the past 10 years, while coniferous forests have decreased by 5%, resulting from human activities, climate fluctuations, and environmental enrichment (eutrophication) (NC – Latvia). The higher value given to the deciduous trees is associated with afforestation programmes on abandoned farms. However, it is important to note, that there has also been a decrease in the traditional broad-leaved tree species, such as oak (-2%) and ash (-12%), which has been replaced by pioneer species such as birch, aspen and grey alder (NC – Latvia).

There have been some benefits in the forest sector over recent decades that can be attributed to climate change. For example, an increase in forest Net Primary Productivity (NPP), the expansion of forest area and an increase in annual increment (NC – Austria, Latvia). Models indicate that an increase in the growth rates can be explained by an increase in temperature and extension of the growing season (NC - Austria).

Box 2 – Examples of Specific Observations form the Temperate Domain:
In Belgium there has been an observed northward migration of species, as well as an increased insect attack on beech, although this cannot be definitively associated with climate change (NC – Belgium).

There has been an observed decay in the coniferous forests of Bulgaria as a result a drying climate. This is mostly occurring in the lowlands (below 800m), which is also where the majority of coniferous forests have been established (NC – Bulgaria).

The German forests showed signs of severe deterioration in 2004, following extreme events and disturbances in previous years, including drought, acid rain and high levels of air pollution (NC – Germany).

In Latvia, there has been an increase in the growing season by an average of 8 days, and is associated with a general warming on the climate (NC – Latvia).

3.3.2 Vulnerabilities and Future Impacts

As the temperate forests are located where conditions are comparatively benign (i.e. not at the outer limit of growing conditions), it is one of the least vulnerable domains. This also correlates to the adaptive capacity of the forest types associated with this domain and importantly the ability and area to migrate as the climatic conditions alter. The regions located within the transition zone of two domains, particularly between the sub-tropical and temperate domains, are most likely to display impacts of climate change, whilst regions that are more centralised within the domain are less likely to display such severe changes (NC – Denmark, Ukraine, New Zealand, Switzerland, and Australia). Additionally artificial or "un-natural" stands, in regards to both species and species composition, e.g. monocultures, are more vulnerable than forests which are in a more natural state, as are healthy forests compared to weaken or degraded forests (NC – Austria, Bulgaria, Czech Republic, Switzerland).

The temperate domain is predicted to have an increase in temperature and winter rainfall and a decrease in snowfall and available water during summer months, which will impact upon forest systems (NC – Austria, Belgium, Belarus, Czech, Germany, Bulgaria, Estonia, Hungary, Italy, Japan, Latvia, Switzerland, Lichtenstein, Lithuania, Slovenia, Sweden, Ukraine,). Larger variations in climatic conditions are also predicted across this domain, i.e. dry periods followed severe storms (NC – Lithuania, Switzerland).

The main vulnerabilities for forests are associated with alterations in the hydrological cycle, in particular through water shortages (NC – Austria, Bulgaria, Belarus, Belgium, Bulgaria, Croatia, Germany, Italy). This can occur directly through a decrease in precipitation, or indirectly as a result of increased temperature and the subsequent increase in evaporation or reduced snow melt (NC – Austria, Belarus, Estonia, Japan, Sweden). The impact of this will be greatest during the warmer months, as this is the time of highest temperature as well as the active growing period for trees (NC – Belarus, Denmark).

The temperate forests are predicted to shift in forest composition due a poleward migration of growing conditions (NC – Austria, Belarus, Belgium, Bulgaria, China,

Estonia, Germany, Hungary, France, Italy, Japan, Lithuania, New Zealand, Slovenia, Sweden, Switzerland,).

3.3.2.1 Topographic Delineation

Climate change is predicted to impact on all forest types in some form, with the severity of the impacts depending on the climatic factors as well as the properties of the forest ecosystems. This noted, the lowlands and the alpine/mountainous regions within the temperate region are most likely to be impacted on by climate change, although as a result of different factors (NC – Australia, Austria, Bulgaria, Germany, and Czech Republic). This is likely to be the result of the predicted changes in the growing season, plant phenology, extreme weather events and the natural disturbance regime.

Lowlands

Changes in climatic conditions, in particular to the hydrological cycle, are likely to have adverse impacts on the temperate lowland forests. In Bulgaria, the lowland forests are the most vulnerable to climate change due to unsuitable species composition (exotic coniferous monocultures) for the current and predicted climate, and are especially vulnerable to drought (NC – Bulgaria).

This has important ramifications for the forest industry in regions where production forests have been established at the limits of growing conditions. There is a high likelihood that these regions will become unsuitable for such forests, as is the case in Bulgaria with coniferous plantations established at altitudes below 800m (NC - Bulgaria).

Lowland forests are also likely to exhibit detrimental impacts of climate change due to water stress (NC – Germany, Czech Republic, Austria). This is likely to result in a decrease in forest connectivity, breaking up the current continuous forests to a more mosaic patterning (NC – Germany). As the lowland areas become more unsuitable for some species, it is predicted that they will migrate upwards in altitude to conditions where they are more suited (NC – Austria, Czech, Germany).

In Switzerland, it may be possible that forests located at the lower altitudes, which are predicted to experience more unfavourable growing conditions, will become a carbon

source in the future, whilst alpine forests, which are predicted to have more favourable growing conditions, are likely to become carbon sinks (NC - Switzerland).

Mountains

One of the most vulnerable forests at the domain level are those located in the mountainous regions (NC – Australia, Austria, Japan, and Slovenia). This is largely due to a limited opportunity for migration and restrictions on genetic diversity as spatial area decreases (NC – Austria). Furthermore, there is a significant lag time reported between observed changes in alpine biota and changes in climatic conditions (NC - Austria).

As a result of increasing temperature, it is expected that there will be a migration of species from the lower to the higher altitudes as the higher altitudes become suitable for regeneration. This includes an increase in altitude of the tree-line by several hundred metres (NC – Italy, Austria, Bulgaria, and Germany). The impacts of this are dependant on regions and the conditions of the mountainous forests systems, with the impacts of climate change ranging from changes in species balance (but not species present) (NC – Germany, Austria), to the local extinctions of alpine species (NC – Austria) .

Within the mountainous regions where there is high rainfall which is not anticipated to be altered dramatically with climate change, such as some areas of Germany, it is expected that there will be an increase in temperature, promoting the upward migration of species (NC – Germany). However, in these regions, it is also expected that existing mountainous species will have the ability to tolerate changes in temperature, and consequently there would not be a change in the species present but rather a change in species composition, with an increase in beech at the expense of pine, for example (NC – Germany)

In circumstances where alpine species are limited in their ability to migrate upwards, due to poor dispersing techniques or poor growing conditions at the higher altitudes, there is a risk of extinction (NC – Austria). A considerable factor limiting the upward

migration of species is air pollution, in particular the high ozone concentration that occurs at high altitudes (NC – Austria, Croatia).

Changes in precipitation and temperature may increase the occurrence of avalanches in mountainous regions, although this prediction is reported as having high uncertainty (NC – Austria, Liechtenstein, and Switzerland). As mountainous forests provide protective functions against such events, their preservation is of importance (NC – Austria). The distribution of these forests is highly sensitive to changes in temperature and the longevity of snow cover (NC – Austria). However, it is not predicted that the ecosystem services associated with protection from avalanches, detritus falls and water erosion in mountainous areas will be adversely impacted by climate change, although this is dependant on the impacts of extreme weather events (NC - Germany).

It is predicted that an increase in drought, flood, fire, frost, snow, and wind storms in mountainous regions will increase the stress in the trees and make them more prone to insect and pathogen attack, such as root disease (*Heterobasidion)* and Fungus (*Armillaria*) (NC – Slovakia, Switzerland).

3.3.2.2 Physiological Changes

Changes in Species composition and Migration

A general warming of the climate is expected to continue to lengthen the growing season, having a number of positive and negative impacts, including increased growth rates and changes in species composition (NC – Austria, Belarus, Belgium, Denmark, Italy, Lithuania, Latvia, Netherlands, Sweden). An extended growing period refers to an increase in the period where conditions, including temperature, are suitable for plant growth, which is also associated with a warmer, shorter, winter period. These two changes are predicted to continue to impact on the phenological characteristics and distribution of plants (NC – Japan, Switzerland, Liechtenstein).

Across the temperate region the poleward migration is anticipated to continue (NC – Austria, Belarus, Belgium, Bulgaria, China, Italy, Ukraine, Russia, New Zealand, Netherlands). It is estimated that there will be a shift in the domain boundaries between 150-500km poleward and up to 500m in altitude (NC – Italy, Japan,

Sweden). This will result in an encroachment of the temperate domain into the boreal, and a loss of area with the expansion of the sub-tropical domain (NC – Austria, Italy, Croatia, France, Sweden).

In the central areas of the temperate domain, this shift is likely to change the species composition of forests, but not the amount of forested area, with a general decrease in the area that is suitable for coniferous forests and an increase in the area occupied by deciduous species (NC – Latvia, Poland, Slovenia, Switzerland, Russia).

In the regions at the transition between domains, or with more marginal growing conditions, there is a predicted increase in the area of steppe and sub-tropical forests at the expense of broad-leaved forests (NC – Belarus, Hungary, & Switzerland). Furthermore, the current species of broad-leaved trees may change, for example in many parts of Europe it is expected that there will be an increase in the area occupied by oak/hornbeam communities at the expense of beech forests (NC - Germany, Switzerland).

The changes in the over wintering period are also likely to impact forest composition. It is anticipated that there will be an increase in winter precipitation across the temperate domain, exceeding the growing conditions of some species, as exemplified by spruce and pine in Belgium and Denmark (NC – Belgium, Denmark).

Phenological changes are also anticipated to occur with a warming of the climate, such as an increase in forest growth and a change in the timing of significant phenological events (e.g. flowering and budding) (NC – Italy, Switzerland, Liechtenstein, Sweden, Japan)

There is a predicted continuation in the trend of early flowering and an early start of growing as a result of shorter winters (NC – Japan & Switzerland). As mentioned in observed impacts, this will be of benefit to many plants as it means an increased growing period, however this benefit may be negated by an increase in the probability of damage to the growing tip from late frosts (NC – Belarus, Sweden), and increased dryness (Belarus, Bulgaria, Czech Republic, Estonia, Japan, Sweden) .

Across the temperate domain there is a predicted increase in the annual growth rates of trees due to CO_2 fertilisation, which increases water efficiency and the rate of photosynthesis (NC – Australia, Austria, Belarus, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Germany, Poland, Sweden, Russia). In Belarus, this growth increase is predicted to be in the order of 25% by 2050, given the estimates on CO_2 concentrations (NC – Belarus). However, it is possible that increased growth will be negated by an increase in major disturbances, such as fire and wind storms, as well as limited by water shortages and air pollution, even after accounting for the increased water efficiency associated with high CO_2 levels (NC – Australia, Austria, and Belgium).

It is possible that there will be a decrease in soil quality, particularly in nutrients, as a result of increased decomposition rates caused by climate change (NC – Belgium). In contrast, other NCs report that the increased decomposition rate will increase growth rates due to an increase in available nutrients (NC – Sweden, Estonia).

It is anticipated that there will be changes in land-uses with the expansion of bio-energy being produced on agricultural land (NC – Belgium).

Genetic Degradation

Genetic diversity is predicted to be reduced as a result of climate change (NC – Belarus, Poland). Within the temperate domain there are some forests that are vulnerable to climate change due to poor genetic diversity at the stand level (NC – Poland, Austria, and Slovenia). Forests which exist in small isolated patches and have limited ability for migration, such as those on mountain tops, are likely to have a limited genetic pool and thus have less resilience to climatic variation (NC – Poland, Austria). A loss in genetic diversity may also lead to a decrease in overall biodiversity. Within Poland, some forest types are at risk of isolation from outside genetics as a result of climate change and may experience degradation as a result (NC – Poland).

As climatic conditions change, promoting the migration of forests, there may be a loss of species diversity as the pioneer species, comprised of a limited number of species, colonise the areas of existing stands (NC – Latvia).

A significant challenge facing all forests is the predicted rate of change. As previously mentioned, it is anticipated that there will be a shift in climatic conditions of up to 500km over the next 100 years, equating to a migration rate of 5km per annum, a rate that exceeds the realistic migration rate of a forest (NC – Italy, Czech Republic). A subsequent loss of genetic and species diversity is anticipated if there is not anthropogenic management.

3.3.2.3 Extreme Events and Disturbances

The majority of communications from within the temperate domain report that there is a predicted increase in the frequency of extreme weather events and large scale disturbances (NC – Australia, Austria, Belarus, Belgium, Croatia, Denmark, Estonia, France, Germany, Hungary, Italy, Japan, Latvia, Lichtenstein, Lithuania, Netherlands, Poland, Slovakia, Slovenia, Sweden, Switzerland, Ukraine, Russia). Fire, wind storms, hurricanes, avalanches, drought, and insect and disease outbreaks are expected to increase in frequency. Although it is reported that these predictions have high uncertainty due to limitations in currently models (NC – Austria) and it is unclear if the observed increase in extreme weather events and disturbances are directly correlated with increasing GHG levels (NC - Switzerland).

The geographic range of insects is predicted to expand with an increase in temperature (NC –Austria, Czech, Bulgaria, Japan, Slovakia, Sweden, Belgium). Consequently it is predicted that there will be a higher species diversity of damaging insects, in higher numbers than has been experienced in the past (NC – Belarus & Belgium). The phenomenon is also likely to hold true for various species of fauna, including wild boar and deer species, resulting in an increase in forest damage (NC – Japan, Latvia).

The previously mentioned predicted decrease in available water is likely to have varying and potentially stand altering impacts on forest ecosystems. An increase in the risk of forest fires is commonly reported throughout NCs, related to increased temperature, and drying of the climate (NC – Australia, Belarus, Croatia, Denmark, Estonia, France, Germany, Hungary, Italy, Netherlands, Russia, Slovenia, Sweden). However, the occurrence of such extreme climatic conditions associated with warmer,

longer, drier summers may also be beneficial, as an increase in fire events, for example, can aid to accelerate species migration and change to a more suitable forest composition (NC – Estonia).

As with drought, insects and fire, an increase in wind damage was raised as a concern within some NCs (NC – Austria, Czech Republic, Germany, Slovakia, Sweden,). As trees become stressed they are more susceptible to wind-throw, which in some regions will be exacerbated during winter months if there is a lack of ground freezing or increased wetness (NC – Czech Republic, Germany, Slovakia, and Sweden). Of particular mention were spruce forests, which are likely to be detrimentally impacted by climate change and vulnerable to wind-throw (NC – Germany, Slovakia).

The Latvian NC identified the increased vulnerability of its coastal zones and forests to wind and water erosion as a result of decreased ground freezing coupled with an anticipated increase in the sea level.

The vulnerabilities and likely impacts of extreme events and disturbances are often interrelated, with the occurrence of one event acting as a catalyst for another (NC – Austria, Estonia, Netherlands, Slovenia, Sweden). For example, drought weakens the natural defences of trees, making them more susceptible to insect and disease outbreaks (NC- Sweden) and also makes forests more susceptible to fire (NC – Estonia, Netherlands, Slovenia). The impacts of extreme events and disturbances are anticipated to have a more immediate impact on forests, with long-term impacts resulting from changes in the prevailing climatic conditions, such as increased temperature and CO_2 levels (NC – Czech Republic).

3.3.2.4 Social Impacts:

Although ecosystem services provided by forested areas are likely to be impacted by climate change as the structure and condition of forests alter, they are not extensively addressed within the vulnerabilities listed in the Annex I NCs. When they are discussed, reference is made to watershed and soil protection, as well as some mention of non-forest products such as berries and mushrooms (NC – Belarus,

Bulgaria). Loss of services from the forest, including detrimental impacts on forest berries and mushrooms due to decreased snow protection during the winter, early growth and late frosts, may also have some impacts on the social arena (NC – Belarus).

Other ecosystem services, in particular recreation, may also be impacted by the changes in forest composition (NC –Lichtenstein, Poland). Additionally, extreme weather events or disturbances may be detrimental to the tourism industry (NC – Slovenia, Latvia).

The impacts of climate change on the forest industry are also varied, and will be dependant on the severity of the changes. The increased growth rates will benefit the industry with shorter rotation times and/or increases in sustainable yield, as well as an increased period for some silvicultural works due to the extended warm period, i.e. planting (NC – Estonia, Belarus). A decrease in growth rates may occur later in the century resulting from higher temperatures and lower rainfall (NC – Romania)

Climate change may have detrimental impacts on the industry due to increased losses from extreme weather and disturbances. Additionally, there is a predicted decrease in the winter harvesting period due to increased temperatures and less ground freezing, thus making harvesting impossible on wet and boggy sites (NC – Belarus, Sweden).

Suitable growing conditions of some production forests, such as Scots pine in Bulgaria, may be exceeded (E.g. insufficient water supply) leading to forest degradation (NC – Bulgaria). Conversely, due to social changes, forested areas within Italy have expanded by approximately 100,000ha per year, between 2000 and 2005, as agricultural land is converted (NC - Italy). More productive species will be able to be introduced to forests due to the changing climate (NC – Belarus).

In Latvia, coastal forests form an important aspect of a protective belt for those who live near the coast (nearly 50% of the population) (NC – Latvia). This belt reduces pollution on the Baltic Sea, decreases erosion and maintains the coastal landscape (NC – Latvia). These protective forests are at risk due to increased erosion resulting from less ground freezing and less coastal ice, which could have detrimental impacts

on those living in coastal areas (NC – Latvia). The Latvian protective coastal belt is defined and protected by law.

3.3.2.5 Summary of Vulnerabilities and Future Impacts

The temperate domain is predicted to experience an increase in temperature and rainfall, but a decrease in snowfall and available water during summer months. Forests that are located at the domain boundaries and in areas with limited dispersal capacity, stressed state, low diversity are the most vulnerable to climate change. The predicted changes in the water cycle are most likely to impact on forests, particular for lowland forests, which are currently in a more stressed state due to anthropogenic activities. However mountainous forests are reported as being more vulnerable to climate change as a result of a limited ability for migration, and air pollution at high levels, particularly ozone.

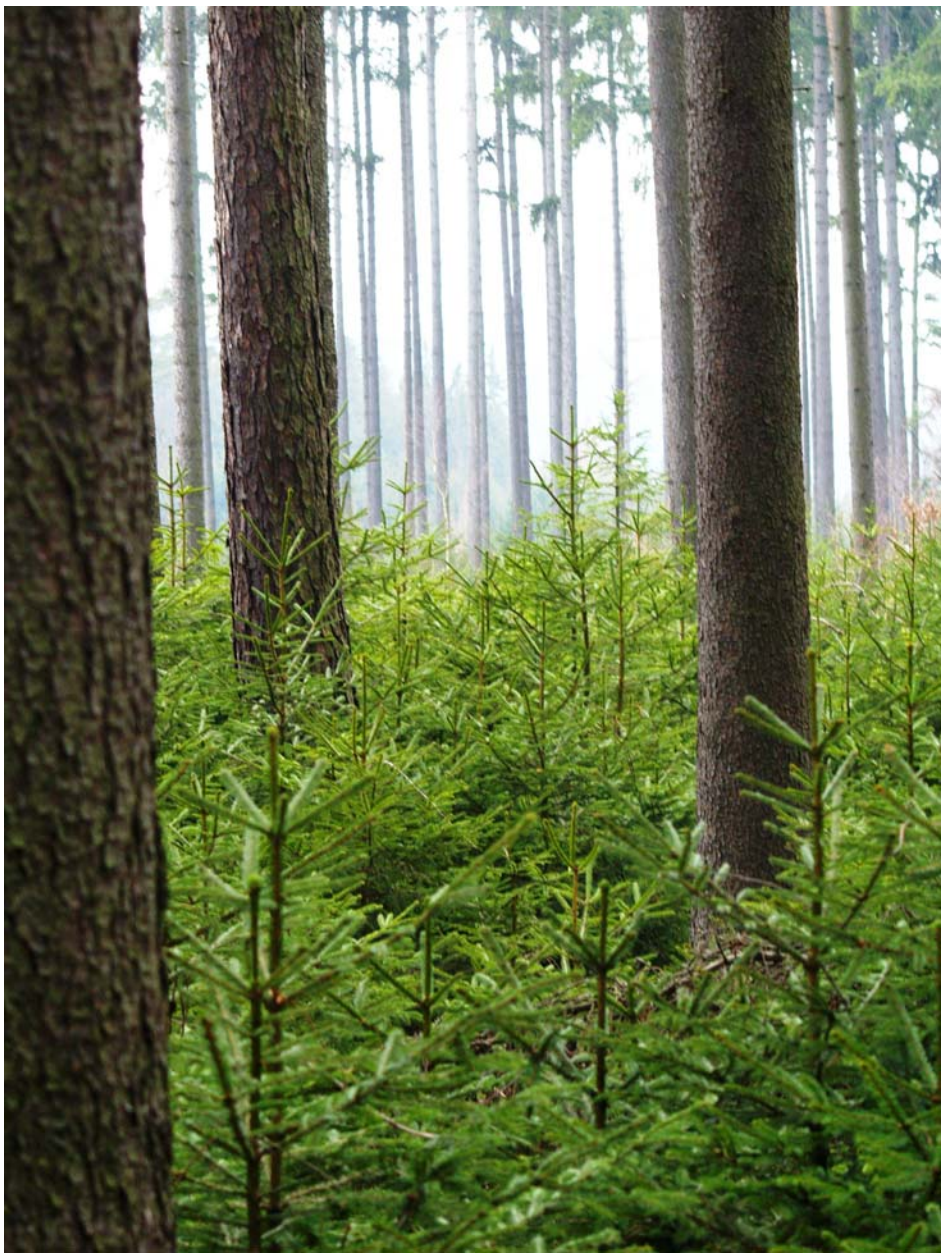
The growth rates of forest species are predicted to increase as a result of CO_2 fertilisation, longer growing period and increased efficiency in photosynthesis.

As a result of climate change it is predicted that there will be a poleward shift in species between 150-500km in latitude and up to 500m in altitude over the next 100 years. This rate of change is reported to be faster than a species can normally migrate, and such migration would be further impeded by fragmented forests. In some regions there will be the expansion of broadleaf species at the expense of coniferous species and an increase in the percentage of pioneer species.

An increase in extreme events and disturbances, including windstorms, fire, drought, insect attacks and diseases is predicted to occur as a result of climate change. With the changed conditions, the geographic range of insects is predicted to expand.

Extreme events such as these are expected to have more immediate impacts on forests, with long-term impacts resulting from changes in the prevailing climatic conditions.

Climate change is predicted to impact on some of the social values of forests, with detrimental impacts on non-wood forest products such as berries, as well on recreation and tourism. With the timber industry, it is expected that the period for silvicultural works will increase as a result of a longer growing period, while there will be reduce opportunity for winter harvesting of wet and boggy sites resulting from less soil freeze.



Temperate coniferous forests, Czech Republic

3.3.3 Management for Adaptation

Through the implementation of appropriate management techniques the impacts of climate change on forests can be reduced, and adaptation promoted. For this to occur, adaptation and adaptive management needs to be incorporated into management plans (NC – Belgium, Australia, Bulgaria). Management should focus on reducing all non-climate stresses on forest systems (Belgium). Natural ecosystems have comparatively less adaptive capacity with regards to climate change than managed forests, as the rate of climate change is predicted to be greater than the adaptive reaction of forest ecosystems (NC – Austria).

The management techniques outlined in the NCs promote the formation of more resilient forests in the face of climate change. Near-nature forest management is advocated as an adaptation option (NC – Austria, Denmark, Switzerland and Ukraine). In such management systems, natural or imitated natural regeneration is indicated as a method of maintaining genetic diversity (NC - Austria, Bulgaria, Switzerland, & Ukraine).

The Bulgarian NC states that by carrying out thinning at an earlier stage, it will be possible to limit the stress on trees due to nutrient and water deficiencies.

Management against extreme disturbances is also considered, with recommendations for improvements in fire detection and suppression techniques, as well as methods for combating pests and diseases (NC – Bulgaria, France, Ukraine, Switzerland). It is reported that through stricter quarantine and stricter sanitary management, the impact of insects and diseases can be minimised (NC – Czech Republic, France). Changes such as this are short to medium term options available for forest managers in order to create a more stable forest and reduce external pressures. Through these measures autonomous adaptation of the forests is promoted (NC – Switzerland). Although these options will aid in resilience against the short and medium term impacts of climate change, forests located in areas where long term climate projections involve significant change, will require further actions (NC – Switzerland).

Options available where management is aimed at mitigating the long term impacts of climate change, such increased temperature and dry periods, generally involve changes in the forest species and composition (NC – Belgium, Belarus). Of particular importance for some regions of the temperate domain is the exceeding of climatic conditions suitable for coniferous stands (NC – Austria, Belgium, Bulgaria, Denmark, Slovenia). Management which creates mixed species composition is promoted for creating more stable forests in such circumstances (NC – Bulgaria, Czech Republic), as is change from coniferous to deciduous species (NC – Austria, Slovenia). This may involve prevention of natural succession of forests by direct planting with climax species, or in order to increase the genetic diversity of a forest, encouraging regeneration from seed sourced from multiple areas rather than replying on coppice regeneration. (NC – Belarus & Slovenia). Furthermore, selective breeding promoting high tolerance to climatic variability is also encouraged (NC – Bulgaria, France & Ukraine).

In areas more vulnerable to moderate changes in climate, such as in the domain transition area, a potential management strategy may be to permit colonisation by new plant species which are more adapted to the new climate (NC – Bulgaria). To aid in the colonisation and migration of species the establishment of nature corridors has been suggested by several countries (NC – Belgium, Poland, Sweden, and Switzerland). Through the creation of reserve systems running north-south, plants and animals would have a greater ability to migrate as the climate changes.

It is expected that the change in climate will exceed the plants natural ability to migrate or adapt (NC – Italy, Denmark). Management may intervene and promote migration, in latitude and altitude, through planting. Included in this may be the expansion of forests onto agricultural land (NC – Latvia, Italy, Belarus, Lithuania, & Slovenia).

3.3.4 Policies for Adaptation and Instruments

Large amounts of temperate forests are located within the more developed regions of the world, such as Europe and North America. Which has implications for adaptation as it is those countries with high financial and human capital can afford to take adaptive measures (NC – Austria).

The measures identified in the NCs are largely forest expansion, SFM, and forest protection although adaptation this is often a secondary impact of the policy, with mitigation being a primary objective. SFM is a means of promoting autonomous adaptation of forests to changes in the climatic conditions (NC – Switzerland). The policies that were introduced concerning adaptation of forests and the forest sector were often incorporated into national and local programmes, such as the National Forest Programme or rural development programmes.

In the context of the vulnerabilities of the temperate domain, there is acknowledgement of changes which need to occur within the industry, at a political and ground level, although much of this appears not to have been translated into policy, or at times preliminary research. The Swiss NC identifies that there is currently a lack of planning for the future disturbances which historically have not been an issue. For example fire is currently an uncommon occurrence in mountainous regions of Switzerland; however it is predicted to become a prevalent issue as the climate changes, yet fire is rarely addressed by climate change impact research.

When a potential problem is identified, and no specific policy is outlined pertaining to the problem, it is common for reference to a National Adaptation Programme or equivalent, where it is stated the adaptation options are addressed. However it is unclear from the NC the depth of the information presented within these programmes, or if policy has been planned or implemented. For example, the Austrian NC states (NC – Austria, p. 129)

> "The necessity of adaptation measures in forestry has also been emphasized in the so-called "Austrian Forest Dialogue", a multi-stakeholder discussion forum on the future of Austrian forests. As a result of the dialogue, the national forest

programme has been established in the year 2005. One of the elements of the national forest programme is the development of a detailed research strategy concerning adaptation and of an information and training concept to disseminate recommendations on this matter."

Additionally, there is a tendency to promote management techniques for the adaptation of forest, as discussed in the previous section, as opposed to mention of specific policy, although often policy would be needed to promote the changes in management. This can be observed in the *In-depth Summary* that has been produced for many of the 4th NCs (Annex 1 – In-depth Review of Fourth NC).

Due to the uncertainty associated with the future events, adaptation options that will be implemented will tend to be an extension and adaptation of current techniques, rather than drastic change, as well as a tendency to favour the financially cheaper options (NC – Czech Republic). Short and medium term adaptation options for forests are increasing the stability of forest stands through changes in management and a decrease in external stresses, while long term options include changes in forest species composition.

Within the NCs the need for the strengthening legislative and economic support for adaptation as well as providing detailed information on adaptation options was identified in order for successful adaptation to be achieved (NC – Australia, Belarus, and New Zealand). It is noted within the Bulgarian NC that as a whole, there needs to be a move away from separation of stakeholders and a more holistic approach taken to tackle adaptation to climate change. Included in this is the cooperation of different ministries, nongovernmental organisations and regional offices, as well as international cooperation.

It is noted within the United Kingdom NC that although there is limited documentation of adaptation measures that have taken place, it may be the case that autonomous adaptation is already occurring.

3.3.4.1 Regulatory Instruments

National forest programmes, national Forest Acts or equivalent processes, are reported as a means of implementing regulatory measures, and can involve the promotion of SFM (NC – Australia, Austria, Denmark, Hungary, Lichtenstein, and Poland). This includes the protection of forests and forest genetics as well as the setting of performance guidelines (see Annex 2 – Overview of presented policy on Mitigation).

Regulations in place within the forest sector include stricter guidelines for forest management including limiting the size of clear-cuts and the promotion of near-natural forest management (NC - Switzerland).

Regulatory policy has been implemented to combat deforestation, for example by the state level legislation on native forest management introduced in Australia (NC – Australia). Although within the NC it is stated that this was primarily done for the reduction of GHG emissions (mitigation) it can also be considered to be a policy related to adaptation as it minimised anthropogenic disturbances on forests, thus increasing resilience.

The Belgium NC identifies that existing policy is lacking foresight in regards to the future climatic conditions, although reactive adaptation has already been incorporated into forest planning and policy (NC – Belgium), supporting a trend of reactive adaptation as opposed to planned adaptation. Also stated in numerous reports is the importance of the incorporation of adaptation to climate change into local and regional planning (NC – Australia, Belarus, New Zealand, United Kingdom). Similarly, other NCs recognise that there is a need for sector based policy and target programmes in order to promote adaptation to new climatic conditions (NC – Belarus and Czech Republic)

Regulatory policy is used to support other instruments, such as economic incentives, to aid in adapting to *physiological changes* resulting from climate change. For example in Belgium regulatory policy is coupled with economic incentives in the form of subsidies to facilitate the change in forest composition, through the planting of tree species which are more suited to the existing and future climate (NC –

Belgium). A number of NCs identified that changes in forest composition have been aided through plantings, however it was not stated if and how this was supported through legislation (NC – Poland, and Czech Republic). The objective of such an action is to increase the natural resilience of the forests to climate change.

In-situ conservation and the use of natural regeneration is viewed is a means of preserving the genetics of forests (NC – Austria). This has been incorporated into the National Forest Programme (NC – Austria).

Placing responsibility for natural hazards, such as *extreme weather events*, onto particular agents, i.e. local governments, is suggested to be an important step in adapting to climate change (NC – New Zealan). These agencies are encouraged to adapt to climate change and incorporate it into planning. It is reportedly better for vulnerabilities to be dealt with at more local levels, as it is difficult to accurately address the uncertainties of extreme events at a national level (NC – New Zealand). In order to provide legal certainty of responsibilities for local governments in New Zealand, the Resource Management Act (2004) was amended to ensure the consideration of climate change at the local level. However, this is not specific to forests or the forest sector.

The *social arena* will also be affected by changes in forests services associated with climate change. For example, the Lichtenstein NC reports that tourism enterprises have changed which activities are undertaken in an attempt to diversify and minimise loss of income. The tourism industry in Lichtenstein is legally bound to the principles of sustainability and is environmentally conscious (NC – Lichtenstein). With respect to climate change, it is noted that the "interfaces for the protection of the landscape are still insufficient with respect to all the demands that have been formulated" (NC - Lichtenstein, p. 56)

3.3.4.2 Economic Instruments

Economic instruments are commonly used throughout the temperate domain to promote afforestation and changes in forest composition (NC – Australia, Ireland, Denmark, Hungary, New Zealand, United Kingdom, Lithuania, and Belgium). This is achieved through grants, subsidies, and compensatory payments. Economic

instruments for afforestation were commonly incorporated into programmes for rural development, land rehabilitation or similar (NC – Australia, Ireland, New Zealand, and United Kingdom).

Lithuania has subsidies for planting and development of the forestry sector through the European Union's funding Programming Document and Rural Development Plan (NC – Lithuania). Economic encouragement for afforestation programmes has also been introduced in Australia, where tax deductions are given to investors in plantation establishment (NC – Australia). Through the use of subsides for planting species better suited to the current and future climate, there have been changes in species composition in Belgium from coniferous to broad-leaved forests (NC – Belgium). Similarly, subsidies are used in Denmark to promote afforestation of agricultural land (NC – Denmark).

Economic instruments are also promoted as a means of improving forest management (NC – Czech Republic, United States of America, Liechtenstein, Sweden). The Czech Republic promotes the use of economic and regulatory instruments to formulate targets and improve the management of forest areas (NC – Czech Republic). Voluntary forest certification systems such as FSC and PEFC are also used for providing financial incentives for SFM (NC – United States of America, Lichtenstein, Sweden).

It is also noted that there are synergies with ecosystem management in other arenas, such as water management, where joint adaptation can be implemented (NC – Netherlands). In the Netherlands for example, compensatory payments are made to landholders for contributions to water and ecosystem management under the 'Green and Blue' imbursement scheme (NC – Netherlands).

Economic instruments are used to increase forest health, promote SFM, and aid recovery from *extreme disturbances* (NC – Switzerland, Denmark). Switzerland for example, has introduced policy whereby rehabilitation works carried out in forests are subsidised, as are prevention measures taken against pests and pathogens (NC – Switzerland). Similarly, the Danish NC reports that Denmark has a statutory windfall fund, which is used to replant areas affected by wind damage. It is reported that

records of species and provinces affected are kept to aid in optimising adaptation (NC – Denmark).

3.3.4.3 Informational Instruments

Dissemination of information concerning the likely impacts of climate change, the economic and financial implications of adaptation measures, as well as guidelines for adaptation and assessing climate change impacts and adaptation options is an invaluable instrument when dealing with climate change.

Within all NCs, programmes which promote the dissemination of information is covered in a separate chapter on E*ducation, Training and Public Participation.* However this is presented in the broader context of climate change, and is not specific to forests or the forest industry.

Information regarding adaptation is often stated to be incorporated within national policy documents, such as VAHAVA (VAltozas-HAtas-VAlaszadas, *change-impact-response*) which was launched by the Hungarian Ministry of Environment and the Hungarian Academy of Science to improve policy related to climate change (NC – Hungary). VAHAVA outlines adaptation options for forests, as well as methods of mitigation such as increasing energy savings, efficiency, usage of renewable energy sources and sustainability (NC – Hungary). This is a common theme amongst countries that have produced a NC (NC – Australia, Austria, Denmark, Latvia, New Zealand, United Kingdom, United States of America).

These national strategies are supported by national monitoring and research programmes targeting the impacts of climate change (NC – Latvia, Australia, New Zealand, United Kingdom). For example the introduction of long term monitoring programmes to observe changes in biodiversity and detrimental impacts of climate change (NC – United Kingdom). The national strategies are used as an umbrella for other projects and initiatives such as the establishing of a national register of seed tree stands and the formation of a gene conservation network (NC -Switzerland).

These research and monitoring programmes can be used for the dissemination of information on the values and benefits of forests in relation to climate change to forest

owners and managers as well as to the general public (NC – Czech Republic, Latvia). Included in this is the promotion of the use of durable timber products, which act as a carbon sink (NC – France).

As with the regulatory and economic policy instruments, within the NCs there is mention of gaps in available informative (NC – Slovenia). The Slovenian NC identifies the need to have a forest categorisation system, whereby forests composition and growing sites are mapped and categorised by their sensitivity to climate change, thus providing information to aid adaptation.

In response to an observed increase in the number of fire events occurring in Italy, successful educational campaigns were launched, subsequently reducing the number of human ignited fires (NC - Italy). Mapping and risk assessments are also an important aspect of adapting to climate change (NC – Australia, France, New Zealand)

3.3.4.4 Summation of Policies for Adaptation and Instruments

Regulatory instruments are incorporated into national forest programmes, Forest Acts or equivalent processes. These include stricter measures on what can be cut, protective legislation stopping deforestation, and general promotion of SFM. In-situ conservation is viewed as a means of increasing the resilience of forests to climate change. In some countries regulatory instruments are used in conjunction with economic instruments is being used to promote species change.

Economic instruments such as grants, subsidies, and compensatory payments are used to promote afforestation and changes in forest species and species composition to form a forest that is better suited to the current and future climatic conditions. Voluntary forest certification systems are also utilised to provide financial incentives for better forest management.

Subsidies are provided for recovery after extreme disturbances and prevention measures against insects and diseases, as well as payments for reforestation following severe windstorms.

Informational instruments are incorporated into national policy documents and outline adaptation options. It is noted that there is a need to disseminate information pertaining to the potential risks and adaptation options available for coping with climate change. Including continued monitoring and research into climate change, the mapping of sensitive areas and forest types, risk assessments, and incorporation of climate change into regional planning.

Temperate mountainous coniferous forests, Austria

3.3.5 Mitigation Measures

There is a trend of policy to focus on mitigation techniques as opposed to adaptation, although it is often difficult to separate the two. Information presented in the previous section will not be included in this section, or will only briefly be mentioned. Generally speaking mitigation is associated with an increase in carbon sequestration through afforestation and SFM which promotes increase growth rates and carbon sequestration (NC – Australia, Austria, Denmark, Estonia, Hungary, Ireland, Japan, Latvia, Lichtenstein, Netherlands, New Zealand, Poland, Romaina, Slovakia, Slovenia, Sweden, Switzerland, United Kingdom, United Stats of America). In many countries afforestation is promoted through financial incentives (tax incentives, subsidies, grants) (NC - Australia, Denmark, Hungary, New Zealand, United Kingdom), with some offering compensation to land holders where there has been lost revenue due to afforestation on agricultural land (NC - Ireland, Belgium). Voluntary and regulatory instruments for afforestation are incorporated into national development plans and national forest programmes; however this is limited to a few countries, such as Slovakia, Estonia. The promotion of wood based energy production as a method of producing carbon neutral energy is also present within some NCs (NC – Austria, France).

It is reported that forests which display stable characteristics in the face of changing climatic conditions are of significant value as a tool for mitigation (NC – Italy). Consequently the promotion of afforestation on abandoned agricultural land in regions where stable forests are located increases the rate of carbon sequestration and long term storage of carbon for climate change mitigation, as is the case in Northern Italy (NC – Italy).

Despite the contribution of forests for carbon sequestration, in the Czech Republic forests are not legislatively recognised as “special purpose forests”, unlike other ecosystem benefits such as watershed protection (NC – Czech Republic).

3.4 Boreal Domain

The boreal domain is located north of the temperate domain and south of the polar, only occurring in the Northern Hemisphere from 50-55 to 65-70 degrees in latitude. It is characterised by 1 to 4 months of average temperatures above 10^{o}C, and low annual rainfall, generally below 500mm. The boreal domain encompasses three GEZ, namely:

1. Boreal coniferous forest,
2. Boreal tundra woodland and,
3. Boreal mountain systems.

The boreal domain incudes large tracts of forested land in northern Eurasia and North America. The vegetation within this domain is dominated by coniferous stands. Spruce *(Picea ssp.)* and fir (*Abies ssp.)* dominate in North America and northern Europe, while larch (*Larix ssp.)* is common in central and eastern Siberia. The boreal GEZs cover approximately 18.9 million km^{2}.

The 6 countries that are located within this domain and have submitted a NC are Canada, Finland, Iceland, Norway, Russia, Sweden and the United States of America.

3.4.1 Observed Impacts

There has been observed climate change in the boreal region, with an increase in average temperature and precipitation (NC – Finland, Canada), although there is limited information reported within the NCs on observed changes in the forest system as a result climate change.

There have been some changes in plant physiology as a result of climate change. In Sweden it has been noted that the sprouting and budding time and leaf fall timing have already altered, while growth rates and vegetation density have increased (NC – Sweden). There has also been a noted change in species distribution with an increase in altitude of some coniferous and deciduous forests in some parts of Sweden (NC – Sweden). The Canadian NC indicated that there have been some observed changes in

ecosystems as a result of climate change. It was reported that milder winters is predicted to have contributed to an outbreak of Mountain Pine Beetle (NC – Canada).

Boreal coniferous forests, Canada

3.4.2 Vulnerabilities and Future Impacts

3.4.2.1 General Vulnerability

As a whole, the boreal region is likely to exhibit changes due to climate change. The most vulnerable forests within this domain are mountainous and alpine forests, as well as those located at the southern extremities of the ecological zone.

The boreal region is subject to similar impacts from climate change as other domains, with an increase in extreme events and disturbances, plant growth and changes in species composition (NC – Canada, Finland, Iceland, Norway, Sweden, and Russia).

The boreal domain is expected to experience an increase in temperature and changes in precipitation as a result of climate change, resulting in warmer summers, wetter conditions in the north (NC – Finland, Norway, and Sweden), and drier conditions in the south (NC – Canada, Russia). These changes are most likely to impact forests that are those located at the southern edge of growing conditions, with poor dispersal (NC – Canada).

3.4.2.2 Topographic Delineation

Mountains

Mountainous and alpine species are highly vulnerable to climate change as it is possible that they will be out competed by lower altitude species, and have a limited in area to migrate (NC – Norway). In the mountainous regions of Sweden the anticipated decrease in snow-cover is likely to negatively impact on soil moisture. This is likely to lead to a change in species composition, in particular a reduction in Downy birch, to the benefit of spruce and pine (NC – Sweden).

The Norwegian NC reports that an increase in snowfall at higher altitudes and latitudes is likely change species composition. It is anticipated that the tree-line altitude will increase, decreasing the area of bare mountain tops within Sweden (NC – Sweden). This change has already been noted with the advance of some coniferous and deciduous forests above previously known tree-lines (NC – Sweden). It is also

expected that in the long term the high altitude spruce and pine will be negatively impacted by climate change as a result of drought and wind stress (NC – Sweden).

3.4.2.3 Physiological Changes

Growth Rates and Migration

As a consequence of climate change it is anticipated that there will be an increase in growth rates, with CO_2 fertilisation, increased nutrient cycling and warmer temperatures being the main contributors (NC – Finland, Norway, Sweden, Iceland, & Russia). However, the benefits are likely to be regulated by other factors such as increased evaporation and water deficiency, which could halt growth in early spring (NC – Iceland, Finland). Nevertheless, there are estimates that there could be an increase in growth rates of up to 40% over the coming century (NC – Finland), with the biggest increases predicted for the northern forests (NC – Finland & Norway).

In regards to the impacts of increased winter precipitation and temperature, the impacts will differ between the northern and southern regions of the boreal domain. It is predicted that the southern boreal forests will display impacts as a result of decreasing snow cover and consequently reduced snow melt, particularly in mountainous forests (NC – Sweden, Norway, Finland). The northern boreal is predicted to experience an increase in snow fall and subsequent later snow melt, resulting in a shorter, although warmer, growing season, also with the greatest impacts on mountainous forests (NC – Sweden, Norway, Finland).

The conditions suitable for boreal forests are predicted to shift northward with the changing climate (NC – Canada, Finland, Iceland, Norway, Sweden, Russia). Currently the expansion of forest onto the northern tundra is inhibited by low summer temperatures, however with the warming of the climate, it is predicted that there will be a northward migration of boreal tree species encroaching into the tundra (NC – Finland).

The southern regions of the boreal domain are also likely to migrate northward as a result of warming and it is predicted that the proportion of deciduous forests species will increase (NC - Sweden, Finland & Russia). Climate models predict a northward

migration of boreal forests of 150-500km (NC – Norway, Finland, Sweden) and upward by 500m over the coming century (NC – Norway). However, the tree growth in these regions is slow and this rate of change is likely to exceed the maximum migration rate of these forests (NC – Finland, Norway), which is estimated at 20-200km per century (NC – Finland).

3.4.2.4 Extreme Events and Disturbances

The boreal forests are reported to be highly vulnerable to increasing fire and insect damage as a result of climate change (NC – Canada, Finland, Iceland, Norway Sweden, & Russia). Concerning the boreal forests of North America, it is anticipated that milder winters will prevail as the norm, reducing damage caused by heavy snow fall, but increasing the over-wintering survival of damaging insects (NC – Canada). An increase in the survival of damaging insects will increase the volume of dead timber, thus increasing the likelihood of a fire event or pathogenic outbreak (NC – Canada). This highlights the complexity and interrelated nature of the impacts of climate change.

It is possible that due to warmer winters, trees will initiate growth before the winter is over, which increases the risk of frost damage (NC – Canada, Finland, Norway, Sweden). There is an increased risk of wet snowfalls which may impact negatively on forest health as a result of branch breakage (NC – Finland). Conversely, the reduced snow cover predicted for some regions of the boreal domain may reduce branch breakage (NC – Canada). Furthermore, there is an increased risk of windfall as a result of reduced ground freezing and changes in wind patterns associated with climate change (NC – Norway & Sweden).

All of the above mentioned impacts of climate change may reduce or negate the benefits from increased growth rates, impacting on the social and economic arenas of nations containing boreal forests (NC – Norway). If left unmanaged, the increase in fire and insect attack has the capacity to make forests a source of CO_2, rather than a sink (NC – Canada).

3.4.2.5 Social Impacts

The boreal forests form a significant source of revenue for many northern countries, and subsequently the forest sector is an important contributor to local and national economies (NC – Canada). In Canada for example, the forest sector contributes to $80 billion per year to the GDP, directly employing over 360,000 people. A loss of income from the forest sector due to increase disturbances and extreme events would have a detrimental impact on these communities (NC – Canada).

The impact of climate change on the forest industry is uncertain, as it is difficult to quantitatively compare the possible benefits and negatives associated with it. In the boreal forests it is likely that there will be an increase in tree growth, as well as the possibility to introduce new commercial species (NC –Sweden). If the predicted growth rates were realised there could be an increase in the volume of timber that could be sustainably cut (NC – Finland). There is also a predicted increase in the amount of hardwood that would be produced in regions where now primarily softwood timber is produced (NC – Finland)

Faster growth rates may however result in a decrease in timber quality, earlier seedling growth may result in increased frost damage, and in Southern Sweden growth may be limited by water deficiency (NC – Norway & Sweden). It is also possible that these benefits will be further negated by increased insect attack, storms and droughts (NC – Norway). The increased occurrence of extreme weather events is expected to result in an increase in insurance premiums for forest holders (NC – Sweden)

Given the rate at which climate change is expected to occur, the forest industry may have problems adapting, as the industry is bound by long rotation times (NC – Norway). The associated changes in timber properties, in particular in wood density, may potentially have flow-on effects on the timber products industry (NC – Norway). There may need to be a change in ground based forest operations and management plans as a result of reduced ground freezing and changes in the level of snow fall, resulting in some areas becoming inaccessible to machinery (NC - Finland).

The boreal forests are also favoured for cultural heritage and are the source of many forest based traditions. Throughout the boreal domain it is commonplace for people to utilise the non-timber products of the forests, in particular berries and mushrooms as well as recreational and traditional hunting (NC – Canada & Finland).

The berries which grow within the boreal forests are vulnerable to damage as a result of decreased snow protection during the winter and the increased risk of breaking dormancy too early due to warm spells (NC – Finland).

The Finnish NC predicts an increase in the population of moose as a result of more favourable climatic conditions, in particular from a decrease in snow cover making food more accessible (NC – Finland). As a consequence the management of the moose population will become increasingly important in order to limit the amount of browsing damage (NC – Finland).

Throughout the boreal domain there are also indigenous people who depend on the forests to contribute to their economy and for the continuation of their heritage. In Lapland (Finland, Sweden, Norway, Russia), the Sami people utilise forests for reindeer husbandry, as do the indigenous people of Canada and Alaska (NC – Finland & Canada). Unlike the moose population, reindeer are expected to suffer from food shortages due to the formation of ice crusts due to wet snow, as well as deeper snow in the northern regions. However, a warming of the temperature may result in an increase in summer food supplies in terms of duration and quantity of available (NC – Finland).

3.4.2.6 Summation of Vulnerabilities and Future Impacts

The boreal domain is predicted to experience an increase in temperature and changes in precipitation, including an increase in snowfall in the northern regions. Heavy snow fall is likely to impact mountainous regions, which are also sensitive to climate change due to limited area to migrate.

An increase in temperature and a longer growing season is predicted to increase the growth rates of plants, as well as trigger an expansion of forest into the tundra at the northern regions of the domain. Similarly the southern boundary of the boreal domain is predicted to shift northwards by up to 500km with a shift toward temperate species.

This domain is highly susceptible to an increased frequency of fires and insect attacks. In the south of the domain it is predicted that there will be less branch breakage resulting from warmer winters, however, this may also result in an increase in damage from late frosts and an increase in windfall from less ground freezing. The interrelatedness of extreme weather events and disturbances is also noted; with one event leaving a forest predisposed to other disturbances and more damage.

The impact of climate change on the forest industry is uncertain. If the predicted growth rates are realized there would then be a subsequent increase in the amount of timber that could be sustainably cut. Additionally, there is a predicted increase in the amount of hardwood that would be produced in regions where primarily softwood timber is produced. Such changes may be negated by an increase in extreme events and disturbances.

Climate change may negatively impact on northern reindeer populations due to limited food during winter, conversely moose populations may increase due to an increase in food in the south.

Boreal, reindeer, Finland

3.4.3. Management for Adaptation

A management technique to aid in the migration of species is to establish a migration corridor between fragmented landscapes (NC – Sweden). Built from south to north, this would increase the potential of flora and fauna to migrate (NC – Sweden). Changes in species composition can be promoted by forest managers in order to make optimal use of the forests under changed climatic conditions (NC – Finland). For example, Southern Finland would most likely use birch species as a replacement for the spruce and pine (NC – Finland).

A precautionary measure has already been introduced in Sweden, with Skogforsk developing a breeding programme aimed at developing lines of trees that would be adapted to the predicted future climate (NC – Sweden). This has been implemented since the early 1990s, and as a result, it may be possible to have a more rapid response to climate change.

In Canada the introduction of prescribed burning is viewed as a viable option for reducing the risk of large scale fire events by 25%-30% (NC – Canada). Various provinces have introduced climate change programmes for combating the increase in major disturbances, in particular to fire and insects

To minimise social impacts, forest managers need to have enough flexibility to react to changes in climate and timber demands (NC – Finland). This includes developing new harvesting techniques which are better suited to changing conditions (NC – Finland). More specifically, adapting to shorter winter harvesting periods as well as softer soils and roads (NC – Sweden & Canada)

3.4.4 Policies for Adaptation and Instruments

3.4.4.2 Regulatory Instruments

In regards to capacity building Finland has launched a National Adaptation Strategy, where it aims at increasing the adaptive capacity of society through economic and regulatory instruments, and implemented through environmental management, environmental impact statements and risk management (NC – Finland). Although forestry is mentioned as an aspect of the National Adaptation Strategy, there was no specific mention of implemented policy concerned with the adaptation of forest to climate change. Under a similar premise to Finland, Norway and Canada reported to be developing a National Adaptation Strategy or equivalent (NC – Finland, Norway, Canada). Sweden is yet to develop a national strategy and Iceland reported to only have minimal investigation into adaptation to climate change (NC – Sweden, Iceland).

As noted in the Canadian NC there have been a number of policies implemented to address the increasing risk of *extreme events and disturbances,* such as fire and insect attacks. This includes the introduction of provincial action plans and strategies for reducing the vulnerability to fire, including the introduction of prescribed burning to alter fuel loads in the forests (NC – Canada). Initiatives such as this have successfully reduced the area burned and the occurrence of large scale fires. It is predicted that through the expansion of programmes such as these, that there will be a reduction on the impacts of climate change on the forest sector (NC – Canada). Other initiatives and strategies, similar to these have been implemented in Canada at a provincial level.

Economic Instruments

A country's ability to adapt to climate change will largely depend on financial and human capacity. Consequently, it is the more developed countries which will be able to adapt with greater ease that less developed countries. As the boreal domain consists of comparatively few, well developed countries, there are good grounds for adaptation (NC – Norway).

Informational Instruments

Existing policy which is concerned with the adaptation of forests has focused on informative instruments to promote adaptation. The Finnish NC identifies that there has been a high amount of research into the impacts of climate change on forests and

the forest sector, however a relatively low level into the adaptations to it. It also states that there is a 10-100 year lead time required for planning and implementation of adaptive strategies. This is supported by other NCs, which report numerous projects aimed at investigating the impacts and vulnerabilities of forests to climate change and distributing the information to forest owners (NC – Canada).

It was noted in the Canadian NC that the main aims for policy on adaptation, in general terms, are to:

1. Raise awareness of adaptation;
2. Facilitate and strengthen capacity for coordinated action on adaptation;
3. Incorporate adaptation into policy and operations;
4. Promote and coordinate research on impacts and adaptation;
5. Support knowledge-sharing networks; and,
6. Provide methods and tools for adaptation planning.

Which are similar objectives to those identified by Finland (Table 1)

Evidently, the NCs of the countries of the boreal region have a general focus on capacity building and to increase the awareness of the impacts and vulnerabilities of climate change, with limited examples of implemented policy for specific vulnerabilities (NC – Canada, Finland).

Boreal, mixed coniferous/deciduous forests, Finland

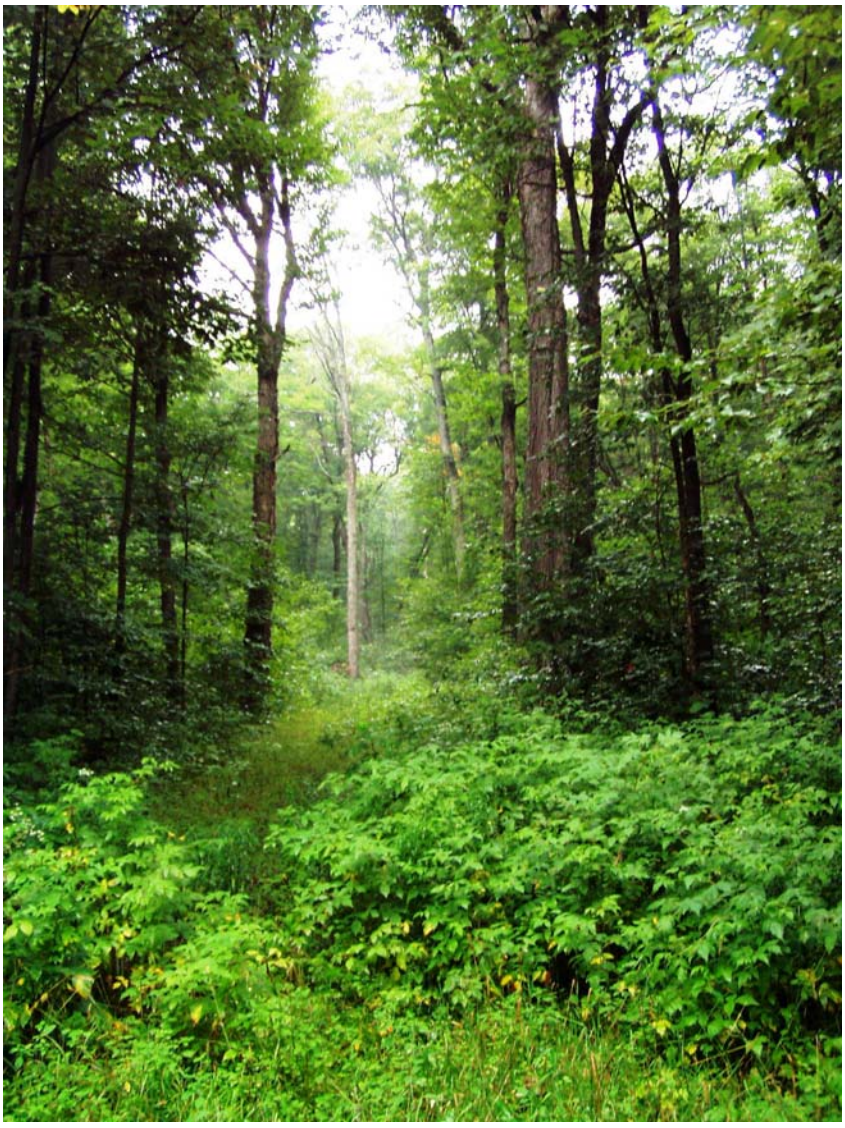
Table 1 - Definitions of policies and measures for adaptation to climate change, as depicted in Finland's National Strategy for Adaptation to Climate Change (2005). Estimates of the timing of the policy are indicated as: *immediate: 2005-2010, **Short term: 2010-2030, ***Long term: 2030-2080. (NC - Finland)

Sector	Instrument	Anticipatory Policy	Reactive Policy
Public	**Administration and planning**	• Inclusion of climate change aspects in the National Forest Programme* • Revision of forest management recommendations to correspond to climate change** • Protection of gene pools of forest trees**	
	Research and Information	• Development of forest management adapting to climate change and mitigating it* • Development of a system for anticipating and monitoring*	
	Economic-Technical Definitions of Policy	• Development of harvesting* • Tree improvement* • Control of pests and diseases*** • Maintenance of forest roads*	• Rapid repair of wind damage in order to prevent consequential damage** • Selection of origin of artificial regeneration material**
	Normative Definitions of Policy	• Assessment of the needs for change in forest legislation in changing climatic conditions**/*** • Potential bans on wood imports from areas most badly contaminated by pests***	
Private		• Preparation of forest plans on the basis of new management recommendations**/***	• Rapid repair of wind damage in order to prevent consequential damage**

3.4.4.5 Summary of Policies for Adaptation and Instruments

National Adaptation Strategies or equivalents outline *regulatory instruments* which will influence environmental management. Some actions have been implemented that reduce the probability of fire and promote prescribed burning.

Informational instruments aim at increasing awareness of adaptation, facilitating coordination of adaptation, incorporate adaptation into planning, research adaptation, and supporting information dissemination. It is noted that although there has been much research into the impacts of climate change, comparatively little has been undertaken on adaptation. Notably, it is also stated that there is a 10-100- year lead time required for planning and implementing adaptive strategies for forests.



Boreal, mix deciduous forests, Canada

3.4.5 Mitigation Measures

Various mitigation programmes associated with the forest industry have been implemented in the boreal domain (Annex 2 – Overview of presented policy on Mitigation). Programmes have been launched which evaluated the feasibility of introducing fast growing plantations and promotes afforestation through the use of economic and educational instruments (NC – Canada & Iceland). The United States of America also identifies the use of technical and financial assistance for the implementation of SFM to promote carbon sequestration (NC – United States of America).

Through National Forest Programmes or equivalents, SFM is promoted, and objectives for the forest sector are set, such as an increase in national roundwood consumption, use of bio-energy, and the expansion of forest protection (NC – Finland & Sweden). This is supported by other national programmes and legislation which promote SFM, including a national certification programmes (NC – Finland). Norway also reports that it has in place policy which promotes increases in the forest resource, however specifics are not detailed. However it is reported that continuous evaluation of existing policy is needed to ensure the correct measures will be taken (NC – Norway).

Young birch leaf, Finland

4. Concluding Remarks

Through the review of the NCs and NAPAs it has been possible to identify the key impacts, vulnerabilities, and some adaptation options to climate change across sectors, as presented from a national perspective. Due to the intrinsic differences of countries within a domain, applicable circumstances vary between countries and no one national report encompasses all issues relevant at the domain level. As such a more comprehensive understanding of predicted impacts and vulnerabilities is only achieved through the combination of multiple national reports. This combination of national reports was complicated by inconsistencies in reporting styles and varying quantity of relevant information presented within the reports. Nevertheless, the combined information is of sufficient quantity and quality for indicative purposes.

The analysed reports indicate that impacts of climate change have already been observed in all domains. This is generally associated with an increase in temperature, changes in precipitation, and an increase in the occurrence of extreme weather events and disturbances, resulting in regional forest degradation and changes in species composition and phenology.

Across all domains it is anticipated changes in forests and the forest sector will continue as a result of climate change, with short-term impacts likely to be associated with extreme weather events and disturbances, and the longer-term impacts resulting from increased temperature and changes in precipitation. Generally there was little distinction made in the national reports between short, medium, and long-term impacts and vulnerabilities or appropriate policies for adaptation at these time scales.

All forest domains are expected to experience a poleward shift in climatic conditions, varying from 100-500km, and up to 500m in altitude. Consequently, there will be changes in species composition. The most vulnerable forests are those with limited dispersal capacity, such as mountainous species, or degraded and stressed forests, such as those located at the limits of ecological zones or growing conditions.

The forests that are located in developing countries, in particular in the tropical domain, appear to be in more immediate danger from anthropogenic activities which are predicted to be exacerbated by climate change. Pressure from deforestation and degradation from subsistence communities, principally for agriculture and the collection of fuel wood, is a running theme throughout the Non-Annex I NCs and NAPAs. The impacts of climate change are not addressed as attentively within the Non-Annex I NCs and NAPAs compared with Annex I countries, with a focus on reducing anthropogenic stress on forests and in-situ conservation, while not detrimentally impacting communities which depend on forests.

In developing countries with communities directly dependent on forests, there is an awareness of promoting non-timber fuel sources to alleviate pressure on existing forests, an opposite stance to more developed countries with less direct dependence on forests, where wood-based fuel is promoted as a carbon-neutral energy source.
NAPA projects aimed at afforestation, community based forest management and community forests are commonly promoted. However, a lack of funding is a likely inhibitor to many of the projects mentioned within the NAPAs.

The information contained in the Non-Annex I NCs and NAPAs depicts the high complexity of the climate change debate and the interactions between the social and environmental arenas. This issue is not presented with the same emphasis in Annex I NCs.

Significant amounts of research into vulnerabilities and impacts of climate change and mitigation are reported by most countries, while research into adaptation is comparatively less, and policy introduced specifically for the adaptation of forests and the forest sector is limited. Specific policy related to adaptation of forests to climate change tends to be focused on general vulnerability, rather than at specific vulnerabilities. These policies are often in the form of national programmes and forest acts with the principle objective of SFM, afforestation, and capacity building through education and increased awareness.

It is notable that measures such as these are promoted as both mitigation and adaptation options. However, it is common for reports not to contain detailed information on how specifically they relate to mitigation and adaptation. Similarly,

the concept of incorporating anticipatory adaptation into SFM is limited in the reviewed reports.

Numerous countries refer to a National Adaptation Plan, which is reported to contain adaptation options, or to the need for such a programme to be developed. Specific examples of adaptation options which have been implemented are scarcer.

As seen from the information presented within this study, existing policy and projects reported in NCs and NAPAs tend to focus on minimising the impact of climate change by preserving existing forests ecosystems, rather than changing them to minimise the damage in the future.

The NCs and NAPAs mention a limited number of forest adaptation policies that relate to specific vulnerabilities. For example, in the temperate domain a predicted increase in damaging windstorms is identified by many countries, while existing policy relating directly to the short term – medium term impacts is limited to only one country, although it is unclear if this is a response to climate change, or to the normal weather conditions. Other countries report on changing species to a more stable composition; however this is a medium to long term programme.

This lack of specificity may be attributed to the fact that the NCs and NAPAs have a broader scope and are not explicitly aimed at forests and the forest sector, and the majority of reports were carried out by the ministries responsible for the environment as opposed to the ministries responsible for forestry.

A theme presented in the reviewed reports is that of increased resilience through forest protection and SFM and indirectly autonomous adaptation. However, multiple reports also state that autonomous adaptation is likely to occur at a rate which is exceeded by the rate of climate change, thus autonomous forest adaptation, such as species migration, may not be able to keep pace with the changes in climate, resulting in forest degradation. As such further actions promoting adaptation seem to be necessary. From the NAPAs it appears that the cost of adapting to climate change is already beyond the capacity of many developing countries, yet a delay in adapting is expected to significantly increase the cost.

The analysis of the reports indicates that when discussing mitigation and adaptation options of forests and the forest sector to climate change, it is difficult, and at times, superfluous, to discuss them as differing entities. The NCs and NAPAs reflect that some forest management and policy options can fulfil the objectives of adaptation, mitigation and sustainable development. As exemplified by SFM and afforestation, which can increase the natural resilience of forests and promote adaptation, while simultaneously maintaining or improving the level of carbon sequestration. Similarly, the incorporation of adaptation into mitigation is needed to ensure the longevity of mitigation programmes.

The reports also indicate that the ability of forests to provide goods and services will be impacted by climate change. Hence, effective policies have to be formulated and implemented in order to ensure that these goods and services (or at least the most important ones) can also be provided in the future. In this context, it can be noted that forest policy makers and practitioners aim to accommodate the diverse, and sometimes conflicting, demands for forest goods and services by means of sustainable forest management, and that adaptive management is a common feature of sustainable forest management already.

The tabling of vulnerabilities and impacts of climate change on forests and the forest sector and corresponding adaptation strategies (Annex 1 – In-depth Review of Fourth NC) reveal limitations, in that specific anticipatory policies relating to a stated vulnerability are rarely reported. Many reports refer to SFM, but fail to specify which particular policies are taken in order to adapt to the environmental changes caused by climate change (Annex 2 – Overview of presented policy on Mitigation Annex 3 – NAPA Projects related to Forests). Similarly, there appears to be a lack of precise measures mentioned within the analysed reports relating to what constitutes SFM, and the correlation between SFM and adaptation to climate change.

Therefore, it is concluded that there are programme deficits. However, it is not possible to determine if this represents the true circumstances or if it is reflecting the broad nature of the national reports, of which forests and the forest sector only form a small subset.

The mere existence of a policy programme or a policy instrument does not necessarily ensure that the expected result will actually be achieved; the outcome depends on the implementation process. Although the key instigators in this process are the implementation agency and the target group, many more participants intervene in the process and determine the final outcome which may more or less deviate from the expected result of the programme ("implementation deficit"). Presently, there is no information available about the national implementation outcomes of forest adaptation policies. In order to provide this, field research in each nation state would be necessary.

The successful implementation of policy promoting adaptation is an essential step in the adaptation process. Through the collation of existing and planned policies relating to the impacts of climate change on forests and the forest sector, as has been carried out in other sectors[7], it would be possible for countries to utilise other countries experiences to formulate more effective policy. The NCs and NAPAs would be a useful platform to form such a database.

Tropical mangrove forest, Australia

[7] See the International Energy Agency Climate Change Policy Database, http://www.iea.org/textbase/pm/index_effi.asp

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Tropical sclerophyllous woodland, Australia

Glossary

Terms and Definitions were obtained from the UNFCCC Glossary[8]:

Adaptation - Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities

Afforestation - Planting of new forests on lands that historically have not contained forests.

Annex I Parties - The industrialized countries listed in this annex to the Convention which were committed return their greenhouse-gas emissions to 1990 levels by the year 2000 as per Article 4.2 (a) and (b). They have also accepted emissions targets for the period 2008-12 as per Article 3 and Annex B of the Kyoto Protocol. They include the 24 original OECD members, the European Union, and 14 countries with economies in transition. (Croatia, Liechtenstein, Monaco, and Slovenia joined Annex 1 at COP-3, and the Czech Republic and Slovakia replaced Czechoslovakia.)

Capacity building - In the context of climate change, the process of developing the technical skills and institutional capability in developing countries and economies in transition to enable them to address effectively the causes and results of climate change.

Carbon sequestration - The process of removing carbon from the atmosphere and depositing it in a reservoir.

Greenhouse gases (GHGs) - The atmospheric gases responsible for causing global warming and climate change. The major GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_20). Less prevalent --but very powerful -- greenhouse gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

[8] UNFCCC Glossary available at http://unfccc.int/essential_background/glossary/items/3666.php

In-depth review (IDR) - A process by which an Annex I Party's implementation of the Convention and/or the Kyoto Protocol is technically assessed by international teams of experts.

Mitigation - In the context of climate change, a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings, and expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere.

National adaptation programmes of action (NAPAs) - Documents prepared by least developed countries (LDCs) identifying urgent and immediate needs for adapting to climate change. The NAPAs are then presented to the international donor community for support.

National communication - A document submitted in accordance with the Convention (and the Protocol) by which a Party informs other Parties of activities undertaken to address climate change. Most developed countries have now submitted their fourth national communications; most developing countries have completed their first national communication and are in the process of preparing their second.

Non-Annex I Parties - Refers to countries that have ratified or acceded to the United Nations Framework Convention on Climate Change that are not included in Annex I of the Convention.

Non-governmental organizations (NGOs) - Organizations that are not part of a governmental structure. They include environmental groups, research institutions, business groups, and associations of urban and local governments. Many NGOs attend climate talks as observers. To be accredited to attend meetings under the Convention, NGOs must be non-profit.

Poleward Shift – Not a UNFCCC definition, but refers to the movement of climatic conditions or plant and animal species to the north in the Northern hemisphere and south in the Southern Hemisphere.

Reforestation - Replanting of forests on lands that have previously contained forests but that have been converted to some other use.

Sink - Any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere. Forests and other vegetation are considered sinks because they remove carbon dioxide through photosynthesis.

Sustainable development - Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable Forest Management (SFM) – No definition was presented in the UNFCCC Glossary

Vulnerability - The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Sub-tropical coniferous plantation, South Africa

Annexes

Annex 1 – In-depth Review of Fourth NC

The following table contains the collated information that was presented in *Report of the centralized in-depth review of the fourth NC* for some Annex I countries which submitted the 4th NC. Outlined are the examples provided on vulnerabilities and adaptation strategies for each of the countries, as well as which policies are being implemented, or what the planned outcome of policies are. The mentioned policies are not specific to a particular vulnerability.

Country	Vulnerability	Adaptation	Policy
Japan	Global warming may result in considerable damage to forests in Japan, e.g. due to decreasing snowfall, resulting in a drier climate		Planned policies and measures in this sector will aim at promoting appropriate management and conservation of existing forests in order to reach the amount of removal units allowed for forest management under the Marrakesh Accords. Further plans address the establishing of new forests, urban parks and green spaces, with the participation of citizens, and promoting the use of timber and wood biomass.
	Habitats and species are expected to move northwards and to higher altitudes; adaptation to climate-induced changes in land use may be also required; some species in the high mountains in the north and west may be affected	Protection and management of sites of special scientific interest; support to agri-environmental schemes by conducting a macro-scale quantitative evaluation of the effects of global warming	
Greece		Combating desertification, especially actions to enhance fire prevention, reforestation, the improvement of degrading forest and forest pastures, and the development of a forest cadastre	Prevention and control of forest fires - Regulation by the Ministry of Rural Development (901 Gg)
		Protection and management of the natural environment through programmes, projects and actions for protected areas and species	
Latvia	Changes in vegetation. Rapid increase of the ratio of unstable forest pioneer stands (birch, aspen and grey alder) and the degradation of stable or so-		Law on Protected Belts, Law on Specially Protected Areas - Forest conservation through restrictions on other activities

	called climax forest stands (stands of spruce, oak and ash)		Improvement in the management of existing forests - Financial support to investment projects
			Afforestation of abandoned agricultural Land – Direct payments
Slovenia	Species and habitats in the periphery of the high Alpine region will have to shift location; risks of forest fires	Preserve forest vegetation	Sustainable Forest Management Programme and regulation
Denmark	Some benefit from increased CO2 concentration, but a negative effect of wind, fire, pests and diseases		National Forest Programme with the goal to double forested area; private afforestation subsidy programme; public afforestation programme
	Habitats and species are expected to move northwards	Protection and management of Sites of Special Scientific Interest; support to agri-environmental schemes	
Iceland	Increasing risks of plant diseases		Enhancement of biological carbon Sequestration - Financial support (ISK 450 million) to a four-year revegetation and tree-planting programme in the period 1997–2000 (207 Gg)
United Kingdom	Some benefit from increased CO2 concentration, but a negative effect of wind, fire, pests and diseases		The UK Forestry Standard; regional forestry strategies
	Habitats and species are expected to move northwards and to higher altitudes; adaptation to climate-induced changes in land use may be also required; some species in the high mountains in the north and west may be affected	Protection and management of Sites of Special Scientific Interest; support to agro-environmental schemes	Woodland Grant Scheme for England
			Woodland planting in Scotland
New Zealand	Some benefit from increased CO2 concentration, but a negative effect of wind, fire, pests, diseases and increased climate variability		Climate Change Forest Package 2004
	Some specific species with a limited climatic “envelope” and several freshwater species requiring cold conditions		Permanent Forest Sink Initiative
			East Coast Forestry Project

Norway	Substantial changes in wildlife and vegetation. The most dramatic consequences may be expected for species that are at the southern or lower limit of their natural arctic and alpine habitats. A rise in temperature will also have some impact on marine as well as fresh water ecosystems	No specific adaptation options reported	Protecting national forests and enhancing forest production through legislation, economic support to forest owners, public funding for education and research, public forest service, forest trust fund for silviculture, and support for infrastructure
	Some benefit from increased CO2 concentration, but a negative effect of wind, fire, pests and diseases may be expected. A warmer climate is also likely to change the composition of forests	Increased readiness of the fire brigades and the rescue service	
Estonia	Some benefit from increased CO2 concentration, but negative effects such as increased forest fire and migration of species are likely		Forest Act 1999 - Detailed legal framework to regulate management of forests to meet environmental and economic objectives. Prescribes an obligation to prepare a forestry development plan at least every 10 years
			Estonian Forest Policy - Implemented through the Forestry Development Plan to 2010, which provides principles and rules for protection and use of forests, sets priorities and activities, and funding for these. The Plan links forestry with wood processing activities and with environmental issues
Sweden	Habitats and species are expected to move northwards and to higher altitudes; some risks may result from fire, insect attack and windfall. A rise in temperature will also have some impact on lake ecosystems		Forestry Act - Increased carbon uptake through improved forest stewardship
	Some benefit from increased CO2 concentration and longer growing	New strategy for the breeding of pine, spruce, birch and *Pinus*	Environmental Code - Increased carbon uptake and reduced CH4

	season, but negative effects from wind, fire, pests and diseases are likely	*contorta* in the early 1990s, which is still applied	emissions through provisions on nature reserves, habitat protection and drainage
			Voluntary measures - Increased carbon uptake through voluntary set-asides
Switzerland	Plant and animal communities living at their ecological limits; high alpine plants in mountain ecosystems; aquatic plants and animals in freshwater ecosystems; forests in general and forestry services	Addressing ecological imperatives through forestry (limiting clear-cutting, regenerating and ensuring sustainability); maintaining the vitality of forests (combating pests and parasites, damage repair); conservation of genetic resources (establishment of registries, gene conservation and seed orchards	National Forest Programme, Parliament decision to choose forest management as an activity under Article 3, paragraph 4, of the Kyoto Protocol
Lithuania	Habitats and species are expected to move northwards, loss of value of protected areas, eutrophication, changes in the populations and migrating habitats of water birds	Increased research, environ-mental protection and ecological farming	Agricultural and Rural Development Strategy; Rural Development Plan - Include measures to increase the area of forest (including afforestation of agricultural land), improve species structure, ensure variety of types of ownership, develop private-sector competitiveness, and increase forest productivity
	Some species are expected to benefit from increased CO2 concentration, but there will be a negative effect of increased pests and diseases	Afforestation	
Finland	Displacement of boreal forests and change of broadleaved forest into boreal forest; extreme weather events: floods and heavy rains, droughts, frosts, storms	Changes in forestry management practices; inclusion of climate change aspects in the National Forest Programme; protection of gene pools of forest trees; forest management adapting to climate change and mitigating it	National Forest Programme (NFP), Finnish Forest Certification System.
Australia			

Annex 2 – Overview of presented policy on Mitigation

The following table depicts specific policy measures related to *Land Use, Land Use Change and Forestry* that have been implemented as reported in the NCs of Annex I nations of the UNFCCC. The information presented is directly extracted from the summary tables for presented within the reports. Also stated are the objective and the policy instrument used. The presented information was extracted directly from the policy summary tables presented in the "Policies and Measures" chapters from the NCs.

Country	Policy/Programme or Measure	Objective	Instrument	Level	NC No.
Australia	Greenhouse Action in Regional Australia	Build capacity to enhance forest sinks and build capacity to reduce emissions from agriculture	Information/ Research	National	4th
	Natural Heritage Trust—land and vegetation programmes (Landcare and Bushcare)	Environmental plantings	Economic/ Information	National	4th
	National Landcare Programme	Environmental plantings	Economic/ Information	National	4th
	Plantations for Australia: The 2020 Vision	Remove impediments to plantation establishment	Economic/ Information	National	4th
	National Action Plan for Salinity and Water Quality	Enhance sink capacity by preventing, stabilising and reversing trends in dryland salinity	Economic/ Information	National	4th
	Queensland Government legislation for the management of native vegetation	Reduce land use change emissions from clearing of native vegetation in Queensland	Regulatory	State	4th
	New South Wales Government legislation for the management of native vegetation	Reduce land use change emissions from clearing of native vegetation in New South Wales	Regulatory	State	4th
	Other land and vegetation programmes	Various activities to improve vegetation management and enhance forest carbon sinks, including legislation covering carbon sequestration	Regulatory/ Economic	State	4th

	Greenhouse Gas Abatement Programme (GGAP)–land use, land use change and forestry elements	Market-based allocation of grants to cost effective abatement opportunities	Economic	National	4th
Austria	Maintenance and extension of vital forests	Maintaining biodiversity, productivity, regeneration capacity and vitality of forests	Information/ Regulatory/ Research	National	4th
Belarus	No Summary Table for Forestry				
Belgium	No Summary Table for Forestry				
Bulgaria	No Summary Table for Forestry				
Canada	Feasibility Assessment of Afforestation for Carbon Sequestration (FAACS)	This initiative evaluated the feasibility of afforestation, undertook information collection and land assessment research on privately owned lands, and contributed to establishing Canada's carbon measurement and accounting infrastructure for reporting internationally on afforestation. Research focused on: landowner consultations; cost-benefit modelling; carbon science development; and, land suitability assessment.	Policy / Research & Development / Awareness	National (Terminated)	4th
	Forest 2020 Plantation Demonstration Assessment (PDA)	Building upon the work of the FAACS initiative, this initiative examined the economics of fast growing tree plantations and potential options to attract investment into future Canadian plantations, by taking advantage of the combined benefits of wood fibre, carbon values and other environmental services.	Policy / Research & Development / Awareness	National (Terminated)	4th

		Forest 2020 PDA approached these goals through: tree plantation demonstration sites; further carbon research; costbenefit analysis of afforestation; and, private sector investment analysis.			
	Forest Enhancement Programme	This programme supports tree planting projects that endeavour to establish healthy, long-term forests or community tree stands; and forest education projects that improve school children's or the public's appreciation and understanding of the nature, role and importance of trees, forests and sustainable forest management in communities, agricultural areas and forest covered areas of Manitoba.	Economic /Information/ Awareness /		
	Ontario Large Scale Forest Carbon Project	Determines the current and future forest carbon balance of Ontario using provincial forest resources inventory (FRI) information and the planned forest management unit silvicultural activities set out in the Strategic Forest Management Model (SFMM), a forest management planning computer model	Research		
Croatia	No Summary Table for Forestry				
Czech Republic	No Summary Table for Forestry				

Denmark	Subsidies scheme for private afforestation on agricultural land	Promote private afforestation in achieving the target of an increase in forest area by 450,000-500,000 ha in 100 years.	Fiscal	National	4th
	Public afforestation (state, counties and municipalities)	Public afforestation in achieving the target of an increase in forest area by 450,000- 500,000 ha in 100 years for purposes such as outdoor recreation, groundwater protection and CO2 sequestration.	Regulation /Voluntary agreements	National	4th
Estonia	Re-forestation of out-of-use agricultural lands (approx. 100 thousand ha)	Build capacity to enhance forest sinks	Regulatory /voluntary	National	4th
	Re-forestation of used mining areas	Build capacity to enhance forest sinks	Regulatory /voluntary	National	4th
European Communities	Forestry strategy	Sustainable Forestry	Resolution	International	4th
	Other forestry measures	Prevention of damage to forests	Regulation	International	4th
Finland	No Summary Table for Forestry				4th
France	Translation not available				4th
Germany	No Summary Table for Forestry				4th
Greece	No Summary Table for Forestry				
Hungary	Afforestation	Increasing the area of	Economic	National	4th

		Forests			
Iceland	No Summary Table for Forestry				4th
Ireland	No Summary Table for Forestry				
Italy	Forestry (2015 -2020: values to be reviewed according to pending international negotiations)	Forest management	Regulatory	National (Planned)	4th
		Afforestation and reforestation (old plantations) and induced re-colonisation areas	Regulatory		
		Afforestation and reforestation (new plantations)	Regulatory		
Japan	Basic Plan on Forests and Forestry	Promote forest and forestry policy that meets an area's various natural, economic and social conditions, bearing in mind an appropriate division of labor with the government		National	4th
Latvia	Increase of forest stand productivity	Increase CO2 removals, provide woodworking industry and energy sector with raw materials	Regulatory: restrictions and prohibitions; Financial: subsidies; Informative: research, workshops, training, dissemination of information	National	4th
	Afforestation of unmanaged agricultural land	Increase CO2 removals, provide wo odworking industry and energy sector with raw materials	Regulatory: restrictions and prohibitions; Financial: subsidies; Informative:		

			research, workshops, training, dissemination of information		
Liechtenstein	Cultivation regulations in the Forestry Act	Sustainable cultivation of forests	Regulation	National	4th
	Ordinance on the scope and benefits of compensation and financial aid in the framework of the Forestry Act	Performance target	Regulation	National	4th
	Ordinance on forest reserves and protected areas	Performance target	Regulation	National	4th
	Forest Inventory 1998 and National Forest Programme	Binding specifications for future use of forests; development of a Forest Inventory 2010	Planning measure/ Regulations	National	4th
	FSC certification of the entire forest stock	Performance target	Operational planning	National	4th
Lithuania	Afforestation and Reforestation	Increase by 3% (11ha) by the year 2021			4th
Monaco	Translation not available				
Netherlands	National Ecological Network Day recreation facilities in urban areas	1 - Conservation, restoration, development and sustainable use of nature to aid biodiversity	Other	Provincial	4th
		2 - realisation of recreation areas in the urban environment to counter continuing shortage of recreational facilities			
New Zealand	East Coast Forestry Project	To facilitate the afforestation of 120,000 of eroding and erodable land in the East Coast region of the North Island over the 28 year period to 2020.	Voluntary/ Fiscal	Local	4th

Norway	No Summary Table for Forestry				4th
Poland	Act of 28 September 1991 on forests (Dz.U. of 2005 No. 45, item 435, as amended)	The Act lays down the principles for preserving, protecting and increasing forest resources, as well as the principles of forest management in conjunction with other elements of the environment and of the national economy.			
	National Programme for the Augmentation of Forest Cover	This Programme sets out measures targeted at increasing the national forest cover from 28% to 30% by 2020. It determines the quantitative transfer of land from agriculture to forestry, and presents a complex action plan towards rationalization of the natural land-use structure of the country's natural habitat area. New afforestations are elements of the implementation of the multifunctional and sustainable development of the country.			4th
Portugal	Programme for the Sustainable Development of Portuguese Forests (in the context of IIIFSP	Promote the sustained increase in forested area, through financial support and incentives to new tree plantations	Economic	National	4th
	Promotion of carbon sink capacity of forests	Increase in the carbon sink capacity of Portuguese forests, through the improvement of forestry management	Economic	National	
Romania	No Summary Table for Forestry				4th
Russia	Translation not available				
Slovakia	Afforestation and increased protection against fire		Regulatory/Economic		4th

Slovenia	Sustainable Forest Management	Preserving the biodiversity, productivity, regeneration ability, volume and vitality of forests	Regulatory	National	4th
Spain	Translation no available				
Sweden	Provisions on forest stewardship etc. in the Forestry Act	Attaining environmental objectives and production targets for forests	Regulatory	National	4th
	Provisions on drainage in the Environmental Code.	Biological diversity	Regulatory	National	
	Provisions on nature reserves and habitat protection in the Environmental Codes and nature conservation agreements	Biological diversity	Regulatory	National	
	Voluntary set-asides, partly through voluntary forest certification systems (FSC and PEFC)	Environmentally sound forestry	Voluntary/negotiated agreement	National	
Switzerland	Sustainability and protection of forested area	Sustainable forest management, no reduction in forested area	Regulatory	National	4th
Turkey	No Summary Table for Forestry				1st
Ukraine	Translation no available				
United Kingdom	Woodland grants scheme (England)	Reforestation and sustainable management of woods	Fiscal (grant)	National – England	4th
	Woodland planting since 1990 (Scotland)	Reforestation	Fiscal (grant)	National – Scotland	4th
United States of America	Forest Land Enhancement Programme	Provides assistance to nonindustrial private forest landowners for forest stewardship, with explicit carbon sequestration goals	Technical/ financial Assistance	National	4th

Annex 3 – NAPA Projects related to Forests

The following table displays the projects which relate to forests and the forest sector in some form. These projects were outlined as priorities in the NAPAs for the corresponding country.

Country	Project Title	Principle Implementing Body	Funding a barrier
Bangladesh	Reduction of Climate Change Hazards through Coastal afforestation with community participation	Forest Body, NGO's and CBOs	Yes
Benin	Support participatory management of gallery forests.		
	Prevention and control of forest fires: capacity development of riverine communities.		
	Support sustainable management of animal biodiversity.		
	Support community planting.		
	Support sustainable management of energy wood.		
Burkina Faso	Sound management of natural resources, valorising non wood forest products (NWFP) in the East of Burkina		
	Promotion of improved stoves, renewable energies and equipments of substituted energy (auto-cooker, water heater and solar-energy dryer etc.)		
Dijbouti	Risk reduction for production systems on the coastal zone through integrative, adaptive and participatory management with community organisations		
	Promote the protection of forest areas at Day and Mabla and introduction of improved stoves		

Bhutan	Promote community-based Forest Fire Management and Prevention	Social Forestry Division, DoF, Ministry of Agriculture fire prone Dzongkhags, rural people and other allied stake holders.	Yes
Burundi	Rehabilitation of Degraded Areas	The Forestry Department, National Coordinator, the National Director, INECN, representatives of all stakeholders.	Yes
	Safeguarding the most Vulnerable Natural Environments	INECN, the National Coordinator, representatives from NAPA Committee, the National Environment Commission,	Yes
	Capacity Building to Promote Energy-Wood Saving Techniques	The framework of the Ministry for Land Management, Tourism and Environment. Forestry Department, the National Director.	Yes
	Education to Climate Change Adaptation	INECN, the National Coordinator, department in charge of woodlots, representatives from all stakeholders. A Steering Committee representatives from the NAPA Committee and the National Environment Commission, members of the biodiversity-related activities coordinating body and representatives from institutions responsible for biodiversity.	Yes
Cambodia	Community Mangrove restoration and sustainable use of natural resources.	MoE, NGOs, local authorities and SEILA.	Yes
	Community agroforestry in costal areas.	Local authorities, MoE, and MAFF's Forestry Administration and Department of Agronomy.	
	Community agroforestry in deforested watersheds.	MAFF's Forest Administration, MoE, NGOs and local authorities.	
Cape Verde	Modernization and diversification of agricultural production for food security improvement.		Yes
Comoros	Defence and Restoration of degraded soils (DRS)	Island Minister of Environment, the Union Ministry in charge of Environment.	Yes
	Reconstitution of the basin slopes	MoE, NGOs, Union Ministry in charge of Environment.	Yes
	Use of non-metallic local materials for the construction of low price housing.	Island Ministry of Environment, with the support of the national laboratory for Public Works, under the coordination of the Union Ministry of Environment.	Yes
Eritrea	Encourage Afforestation and Agroforestry through Community Forestry Initiative	MoA and its regional branches.	Yes
	Groundwater Recharging for Irrigation wells	MoA, WRD.	Yes

Ethiopia	Community based carbon sequestration in the Rift Valley system of Ethiopia.	Environmental Protection Authority	Yes
	Promotion of on Farm and Homestead Forestry and Agroforestry in Arid, Semi-Arid and Drysub Humid Parts of Ethiopia.	Ministry of Agriculture and Rural Development (MoRAD)	Yes
Guinea	Promotion of agroforestry		
	Promotion of appropriate technologies in adaptation		
	Promotion of fire management and protection of forests		
Haiti	Reforestation, conservation and protection of fruit and forest trees in the South-East department		
	Reconstitution and protection of natural sites in the North-East		
Guinea-Bissau	Rehabilitation of Small Perimeters of Mangrove Soils for growing of rice	The Directorate General of Water Resources, Ministry of Public Health, NGOs.	No
	Reforestation of Degraded Zones Project	Ministry of Agriculture and Rural Development through the Directorate General of Forests and Fauna;	No
Kiribati	-		
Lesotho	Management and Reclamation of Degraded and Eroded Land in the Flood Prone Areas (Pilot project for Western-Lowlands).	The project will be implemented by the Ministry of Forestry and Land Reclamation working closely with Local Government and community organizations.	Yes
Malawi	Restoring forests in the Upper, Middle and Lower Shire Valleys catchments to reduce siltation and the associated water flow problems:	Department of Forestry	No
Maldives	-		
Mauritania	Substitution of ligneous fuel		Yes
	Institutional reinforcement of the structure responsible for nature conservation		No
	Improvement of knowledge of the resource and its sustainable management.		No
	Fixation of shifting dunes threatening the national socioeconomic infrastructure		Yes

	Participatory reforestation for energy and Agroforestry in the agricultural zones		Yes
	The protection and reinforcement of the dune bar along the coastline in Nouakchott		No
Niger	Mobilization of surface water and exploitation of ground water	Agricultural development departments, water resources services.	Yes
	Development of anti-erosion infrastructures (CES/DRS) for agricultural forestry and pastoral purposes	Ministry of Agricultural Development, Ministry of Water Resources and Environment, Village Development Committee, CNEDD.	Yes
	Popularization of animal and vegetative species that are most adapted to climatic conditions	Ministry of Agriculture, Ministries of Animal Resources and Environment, Executive Secretariat of the CNEDD.	Yes
Rwanda	Conservation and protection of lands against erosion and floods at district level in vulnerable regions	Project coordination, MINITERE, MININFRA, Districts, Provinces.	Yes
	Increase the capacity of adaptation of villages "Imidugudu" in vulnerable regions through improvement of drinking water and sanitation and alternative energy services and promotion of non-agricultural activities.	Project coordination - MINITERE, - MININFRA, - ELECTROGAZ,	No
	Preparation and implementation of woody combustible substitution national strategy to combat the deforestation and put a brake on erosion due to climate change.	MINITERE, MININFRA, MININTER, ELECTROGAZ, REMA; Research institutes: KIST, IRST, Private sector: Individuals and professional associations, Decentralized structures: Districts and Sectors.	Yes
Samoa	Reforestation, Rehabilitation & Community Forestry Fire Prevention Project	Ministry of Agriculture, Fire Services, Samoa Water Authority	High costs
	Climate Early Warning System Project	Implementing Agency: MNREM Coordinating Agency: MNREM, Steering Committee	High training costs
	Establishing Conservation Programmes in Highly Vulnerable Marine & Terrestrial Areas of Communities Project	MNREM and MOA in close collaboration with communities	Yes
Sao Tome	Sustainable management of forestall resources	The Forests sector of Ministry of the Economy, Cabinet of Environment, the Services of Intern Order, the Autarchies, the	Yes

		Associations of the Small and Medium Farmers, NGOs and all economics sector operators.	
	Introduction of the new technologies for firewood use and to make charcoal.	Rural communities and NGOs	No
	Sustainable management of water and energy	Project to be managed by DRNE, EMAE and Forests sector.	No
	Introduction of renewable energies (solar, wind and biomass).	Natural Resources and Energy and the Forests sectors.	No
Sudan	Enhancing resilience to increasing rainfall variability through rangeland rehabilitation and water harvesting in the Butana area of Gedarif State	The description of highest priority projects did not give any implementing body names.	Yes
	Reducing the vulnerability of communities in drought-prone areas of southern Darfur State through improved water harvesting practices		
	Environmental conservation and biodiversity restoration in northern Kordofan State as a coping mechanism for rangeland protection under conditions of increasing climate variability		
	Strategies to adapt to drought-induced water shortages in highly vulnerable areas in Central Equatorial State		
	Enhancing the resilience of water-stressed agricultural systems through agroforestry in River Nile State		
	Rehabilitation of gum arabic belt for poverty reduction, combating desertification and conservation of biodiversity		
	Rehabilitation of gum arabic belt for increase of resilience, diversification of livelihoods and conservation of resources in Alrahad locality		
	Development of social forestry schemes in Sharia,		

	Almalam, Muhagria, Dirbat, Mershing Agro forestry to increase the adaptive capacity to climate changes in west Juba areas.		
Zambia	Management of critical habitats	ZAWA, MTENR Department of Water Affairs (DWA) communities	Yes
	Promote natural regeneration of indigenous forests	Department of Forestry and Communities.	
	Eradication of Invasive Alien Species	Department of forestry and communities	
Tanzania	Climate Change Adaptation through Participatory Reforestation in Kilimanjaro Mountain.	Ministry of Natural resources and Tourism, Ministry of Energy and Minerals, Local Government Authority, Academic and Research Institutions, local communities, Local NGOs/CBOs	Yes
	Community Based Mini-hydro for Economic Diversification as a result of Climate Change in Same District.	Ministry of Energy and Minerals in collaboration with Local Government Authority, Ministry of Natural Resources and Tourism, local communities and NGOs/CBOs.	
Tuvalu	Increasing resilience of Coastal Areas and Community Settlement to climate change.	Department of Lands (DOLS), Public Works Department (PWD) and Island Kaupule.	Yes
Uganda	Community Tree Growing Project	Forestry Resource Research Institute (FORRI) of the National Agricultural Research Organization (NARO). NFA, MWLE, MAAIF, ENR/SWG, NAADS and Department of Information in the President's Office.	Yes
	Indigenous Knowledge (IK) and Natural Resources Management Project	The Ministry of Water, Lands and Environment (Department of Meteorology)	Yes
Vanuatu	Agriculture & Food security	Department of Agriculture and Rural Development (DARD), Department of Health Food Technology Centre, Department of Forestry and Vanuatu Quarantine & Inspection Services, NACCC.	No
	Sustainable Forestry Management	The Department of Forestry, Departments of Agriculture, Livestock, Lands and Environment, NACCC.	No
	Integrated Water Resource Management	Departments of Geology, Mines and Water Resources and Agriculture, Departments of Forestry, Lands and Environment, NACCC.	No

Annex 4 – Incorporated Reports

The following table indicates which reports were analysed in the formation of this report, as well as the departments responsible for the formation of the NC or NAPA. Also indicated is the domain which the countries were allocated to.

No.	Country	Report	Grouping	Domain	Year Released	Responsible Department
1	Australia	Fourth NC	Annex I	Temperate; Sub-Temperate; Tropical	2005	Department of the Environment and Heritage - Australian Greenhouse Office
2	Austria	Fourth NC	Annex I	Temperate	2006	Federal Ministry of Agriculture, Forestry, Environment and Water Management
3	Belarus	Second, Third, Fourth NC	Annex I	Temperate	2006	Ministry of Natural Resources and Environmental Protection of the Republic of Belarus
4	Belgium	Fourth NC	Annex I	Temperate	2006	National Climate Commission - Federal Public Service Health, Food Chain Safety and Environment
5	Bulgaria	Second NC	Annex I	Temperate		Ministry of Environment and Water
6	Bulgaria	Third NC	Annex I	Temperate	2002	Ministry of Environment and Water
7	Bulgaria	Fourth NC	Annex I	Temperate	2006	Ministry of Environment and Water
8	Canada	Fourth NC	Annex I	Boreal	2006	Government of Canada
9	Croatia	Second, Third, Fourth NC	Annex I	Temperate; Sub-Tropical	2006	Ministry of Environmental Protection, Physical Planning and Construction
10	Czech	Fourth NC	Annex I	Temperate	2005	Czech Hydrometeorological Institute - Ministry of Environment of Czech Republic
11	Denmark	Fourth NC	Annex I	Temperate	2005	Environmental Protection Agency - Danish Ministry of the Environment

12	Estonia	Fourth NC pt1	Annex I	Temperate	2005	Ministry of the Environment
13	Estonia	Fourth NC pt2	Annex I	Temperate	2005	Ministry of the Environment
14	Finland	Fourth NC	Annex I	Temperate; Boreal	2006	Ministry of the Environment
15	France	Fourth NC	Annex I	Temperate and Sub-Tropical	2006	Ministère de L'Écologie et du Développement Durable
16	Germany	Fourth NC	Annex I	Temperate	2006	Government of Federal Republic of Germany
17	Greece	Fourth NC	Annex I	Sub-Tropical	2006	Ministry for the Environment, Physical Planning and Public Works
18	Hungary	Fourth NC	Annex I	Temperate	2005	Hungarian Ministry of Environment and Water
19	Iceland	Fourth NC	Annex I	Boreal	2006	Ministry of Environment
20	Ireland	Fourth NC	Annex I	Temperate	2007	Department of the Environment, Heritage and Local Government
21	Italy	Fourth NC	Annex I	Sub-Tropical; Temperate	2007	Ministry for the Environment, Land and Sea
22	Japan	Fourth NC	Annex I	Temperate; Sub-Tropical	2006	Government of Japan
23	Latvia	Fourth NC	Annex I	Temperate	2006	Ministry of Environment
24	Liechtenstein	Fourth NC	Annex I	Temperate	2005	Government of the Principality of Liechtenstein
25	Lithuania	Fourth NC	Annex I	Temperate	2005	Ministry of Environment of the Republic of Lithuania
26	Monaco	Fourth NC	Annex I	Sub-Tropical	2005	
27	Netherlands	Fourth NC	Annex I	Temperate	2005	Directorate General of the Environment - Ministry of Housing, Spatial Planning and the Environment
28	New Zealand	Fourth NC	Annex I	Temperate; Sub-Tropical	2006	Ministry for the Environment
29	Norway	Fourth NC	Annex I	Boreal	2005	Norwegian Ministry of the Environment
30	Poland	Fourth NC	Annex I	Temperate	2006	Ministry of the Environment

31	Portugal	Fourth NC	Annex I	Sub-Tropical	2006	Institute for the Environment
32	Romania	Fourth NC	Annex I	Temperate	2006	
33	Russia	Fourth NC	Annex I	Temperate; Boreal	2006	
34	Slovakia	Fourth NC	Annex I	Temperate	2005	Slovak Hydrometeorological Institute - Ministry of the Environment
35	Slovenia	Fourth NC	Annex I	Temperate	2006	Ministry of Environment and Spatial Planning
36	Spain	Fourth NC	Annex I	Temperate	2006	
37	Sweden	Fourth NC	Annex I	Temperate; Boreal	2005	Ministry of Sustainable Environment
38	Switzerland	Fourth NC	Annex I	Temperate	2005	Swiss Agency for the Environment, Forests and Landscape
39	Turkey	First NC	Annex I	Sub-Tropical	2007	Ministry of Environment and Forestry
40	Ukraine	Second NC	Annex I	Temperate	2006	
41	United Kingdom	Fourth NC	Annex I	Temperate	2006	Department of Environment, Food and Rural Affairs
42	United States	Fourth NC	Annex I	Temperate	2006	
43	Argentina	Second NC	Non-Annex I	Sub-Tropical	2007	
44	Bahrain	Initial Communication	Non-Annex I	Sub-Tropical	2005	General Commission for the Protection of Marine Resources, Environment and Wildlife
45	Brazil	Initial Communication	Non-Annex I	Tropical and Sub-Tropical	2004	General Coordination on Global Climate Change - Ministry of Science and Technology
46	Cameroon	NC	Non-Annex I	Tropical	2005	Ministere de L'Environnement et des Forets
47	China	Initial Communication	Non-Annex I	Sub-Tropical; Temperate	2004	
48	Fiji	First NC	Non-Annex I	Tropical	2005	Department of Environment
49	Gabon	Communication Nationale	Non-Annex I	Tropical	2005	Direction Générale de l'Environnement

50	Guinea-Bissau	Initial Communication	Non-Annex I	Tropical	2005	Direction Générale de l'Environnement
51	India	First NC	Non-Annex I	Tropical	2004	Ministry of Environment and Forests
52	Madagascar	Initial Communication	Non-Annex I	Tropical	2004	Ministère de L'Environnement, des Eaux et des Forets
53	Mexico	Third NC	Non-Annex I	Sub-Tropical; Tropical	2006	Instituto Nacional Ecologia - Secretario Medio Ambiente y Recursos Naturales
54	Nepal	Initial Communication	Non-Annex I	Tropical	2004	Ministry of Population and Environment
55	Rwanda	Initial Communication	Non-Annex I	Tropical	2005	Ministry of Lands, Environment, Forestry, Water and Mines
56	Saudi Arabia	Initial Communication	Non-Annex I	Tropical; Sub-Tropical	2005	Presidency of Meteology and Environment
57	Sierra Leone	Initial Communication	Non-Annex I	Tropical	2007	
58	Sao Tome e Principe	Initial Communication	Non-Annex I	Tropical	2004	Ministère de Ressources Naturelles et l'Environnement
59	Solomon Islands	Initial Communication	Non-Annex I	Tropical	2004	Ministry of Tourism, Culture and Aviation
60	Suriname	First NC	Non-Annex I	Tropical	2005	Ministry of Labor, Technological Development and Environment
61	Tonga	Initial Communication	Non-Annex I	Tropical	2005	Department of Environment
62	Turkmenistan	Initial Communication	Non-Annex I	Sub-Tropical; Temperate	2006	National Institute of Desert, Flora and Fauna - Ministry of Nature Protection of Turkmenistan
63	United Arab Emirates	Initial Communication	Non-Annex I	Tropical	2006	Ministry of Energy
64	Uruguay	Second NC	Non-Annex I	Sub-Tropical	2004	Dirección Nacional de Medio Ambiente - Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente
65	Venezuela	First NC	Non-Annex I	Tropical	2005	Ministerio de Ambiente y de los Recursos Naturales
66	Benin	National Adaption Programme of Action	NAPA	Tropical	2008	Ministere de L'Environnement et de Protection de la Nature

67	Burkina Faso	National Adaption Programme of Action	NAPA	Tropical	2007	Ministere de L'Environnement et du Cadre de Vie
68	Djibouti	National Adaption Programme of Action	NAPA	Tropical	2006	Ministere de L'Habitat, de L'Urbanisme, de L'Environnement et de L'Amenagement du Territoire
69	Guinea	National Adaption Programme of Action	NAPA	Tropical	2007	Ministere De L'Agriculture, De L'Evevage, De L'Environnement, des Eaux et Forets
70	Haiti	National Adaption Programme of Action	NAPA	Tropical	2006	Ministere de L'Environnement
71	Madagascar	National Adaption Programme of Action	NAPA	Tropical	2006	Ministere de L'Environnement, des Eaux et Forets
72	Mali	National Adaption Programme of Action	NAPA	Tropical	2007	Ministere de L'Equipement et des Transports
73	Democratic Republic of Congo	National Adaption Programme of Action	NAPA	Tropical	2006	Ministere de L'Environnement
74	Senegal	National Adaption Programme of Action	NAPA	Tropical	2006	Ministere de L'Environnement et de la Protection de la Nature
75	Bangladesh	National Adaption Programme of Action	NAPA	Tropical	2005	Ministry of Environment and Forest Government of the People's Republic of Bangladesh
76	Bhutan	National Adaption Programme of Action	NAPA	Tropical	2006	National Environment Commission - Royal Government of Bhutan
77	Burundi	National Adaption Programme of Action	NAPA	Tropical	2007	Ministry of Land Management, Tourism and Environment
78	Cambodia	National Adaption Programme of Action	NAPA	Tropical	2006	Ministry of Environment
79	Cape Verde	National Adaption Programme of Action	NAPA	Tropical	2007	National Meteorology and Geophysics Institute - Ministry of Environment and Agriculture
80	Comoros	National Adaption Programme of	NAPA	Tropical	2006	Ministry of Rural Development,

		Action				Fisheries, Handicraft and Environment
81	Eritrea	National Adaption Programme of Action	NAPA	Tropical	2007	Department of Environment - Ministry of Land, Water and Environment
82	Guinea-Bissau	National Adaption Programme of Action	NAPA	Tropical	2006	Ministry of Natural Resources and Environment
83	Kiribati	National Adaption Programme of Action	NAPA	Tropical	2007	Environment and Conservation Division - Ministry of Environment, Land, and Agricultural Development
84	Lesotho	National Adaption Programme of Action	NAPA	Sub-Tropical	2007	Lesotho Meteorological Services - Ministry of Natural Resources
85	Malawi	National Adaption Programme of Action	NAPA	Tropical	2006	Environmental Affairs Department - Ministry of Mines, Natural Resources and Environment
86	Maldives	National Adaption Programme of Action	NAPA	Sub-Tropical	2008	Ministry of Environment, Energy and Water
87	Mauritania	National Adaption Programme of Action	NAPA	Tropical	2004	Department of Environment Project Coordination Unit - Ministry of Rural Development and Environment
88	Niger	National Adaption Programme of Action	NAPA	Tropical	2006	National Environmental Council for Sustainable Development
89	Rwanda	National Adaption Programme of Action	NAPA	Tropical	2006	Ministry of Lands, Environment, Forestry, Water and Mines
90	Samoa	National Adaption Programme of Action	NAPA	Tropical	2005	Ministry of Natural Resources, Environment and Meteorolgy
91	Sao Tome	National Adaption Programme of Action	NAPA	Tropical	2006	Ministério dos Recurdos Naturais e Ambiente
92	Sudan	National Adaption Programme of Action	NAPA	Tropical	2007	Higher Council for Environment and Natural Resources - Ministry of Environment and Physical Development
93	Tanzania	National Adaption Programme of Action	NAPA	Tropical	2007	Division of Environment - Vice President's Office
94	Tuvalu	National Adaption Programme of	NAPA	Tropical	2007	Department of Environment - Ministry

		Action				of Natural Resources, Environment, Agriculture and Lands
95	Vanuatu	National Adaption Programme of Action	NAPA	Tropical	2007	National Advisory Committee on Climate Change
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